New York State
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

Division of Water

Virgil Creek

Biological Assessment

2005 Survey

New York State
Department of Environmental Conservation
Region 1

George E. Pataki, Governor   Denise M. Sheehan, Commissioner

Virgil Creek

BIOLOGICAL ASSESSMENT

Seneca-Oneida-Oswego River Basin
Cortland and Tompkins Counties, New York

Survey date: July 26, 2005
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Stream: Virgil Creek, Cortland and Tompkins Counties, New York

Reach: Virgil to Freeville, New York

NYS Drainage Basin: Seneca-Oneida-Oswego River Watershed

Background

The Stream Biomonitoring Unit sampled Virgil Creek in Cortland and Tompkins Counties, New York, on July 26, 2005. The purpose of the sampling was to assess overall water quality, compare to previous findings, and assess any impacts of a recent stream reconstruction project.

In riffle areas at six sites, a traveling kick sample for macroinvertebrates was taken using methods described in the Quality Assurance document (Bode et al., 2002) and summarized in Appendix I. The contents of each sample were field-inspected to determine major groups of organisms present, and then preserved in alcohol for laboratory inspection of a 100-specimen subsample from each site. Macroinvertebrate community parameters used in the determination of water quality included species richness, biotic index, EPT richness, and percent model affinity (see Appendices II and III). Expected variability of results is stated in Smith and Bode (2004). Table 2 provides a listing of sampling sites and Table 4 provides a listing of all macroinvertebrate species collected in the present survey. This is followed by macroinvertebrate data reports, including raw data from each site. Fish communities were also sampled in August 2005 using methods described in Appendix XII. Table 3 provides a listing of all fish species collected in the present survey. Expanded habitat analysis was also performed at all sites.

Results and Conclusions:

1. Water quality in Virgil Creek ranged from non-impacted to slightly impacted, based on resident macroinvertebrate communities. The reach from Dryden to Freeville displayed substantially worse water quality than in 1987. Nutrient enrichment is a primary factor in the impact.

2. Water quality declined slightly downstream of the stream realignment between Stations-B and -C; the change mostly reflects nutrient enrichment, and is likely related to soil disturbance incurred during the realignment process.

Discussion:

Virgil Creek originates north of Virgil in Cortland County, New York, and flows approximately 15 miles in a westerly direction, through the town of Dryden, before flowing into Fall Creek near Freeville, Tompkins County. The stream is classified as C(TS) from the source to Tributary 15a, 0.3 mile below Station-1 in Virgil, and C(T) from there to the mouth. Virgil Creek receives annual spring stocking of brown trout.

Virgil Creek was previously sampled by the Stream Biomonitoring Unit at Stations-1 to -3 in 1980 and 1987, and by the NYSDEC Avon Pollution Investigations Unit in 1975. The 1975 study, conducted prior to rerouting of the Dryden (V) Wastewater Treatment Facility (WWTF) discharge to Fall Creek (Preddice, 1975), found a reduction in macroinvertebrate species richness downstream of the discharge (Station-2) and a recovery at Johnson Road (Station-3). The 1980 study (unpublished) also found a reduction in species richness downstream of the discharge (Station-2) and a recovery at Johnson Road (Station-3). The 1987 study (Bode et al., 1987), conducted after the re-routing of the discharge, showed non-impacted water quality at all 3 sites. A later recalculation of the metrics, including percent model affinity (a metric adopted in 1989), resulted in a profile number of 7.49 for Station-2, just short of the non-impacted range. Station-3 was sampled in 2001, as part of the Rotating Intensive Basin Studies (RIBS) monitoring program (unpublished data), and was assessed as slightly impacted by nutrient enrichment.

The purpose of the present sampling was to assess overall water quality, compare it to previous findings, and document any impacts of a recent stream realignment project. A portion of the stream, approximately 0.4 mile between Stations-B and -C was relocated 50-100 meters away from Lake Road, into an older stream bed, to prevent further erosion near the road. The project was initiated in September, 2002 and completed in June, 2005.

In the present study, water quality in Virgil Creek ranged from non-impacted to slightly impacted, with water quality declining slightly downstream of the realignment reach (Figure 1). Impact Source Determination showed nutrient enrichment to be a major factor in the decline. Nutrient Biotic Index (NBI), recently developed by Smith (2005) to evaluate levels of nutrient enrichment, was applied to the data. The values for NBI-P (for total phosphorus) in Virgil Creek ranged from 5.53 to 7.24, with all sites downstream of the realignment reach being in the eutrophic range of 6 or greater (Figure 2).

Examining the change downstream of the realigned section between Stations-B and -C, one metric stayed the same, one declined and two improved. The dominant species remained the same. Nutrient enrichment is a logical product of erosion, soil disturbance and runoff, elements that were likely incurred during stream realignment. The nutrient enrichment downstream of the realignment is considered slight, and the effects are likely not long-lasting.

Stations-1 to -3, from Dryden to Freeville, all displayed poorer water quality compared to 1987 conditions (Figure 1b). It is not known if the decline is related the increases in nutrient enrichment. Since Station-3 was also assessed as slightly impacted in 2001, it is likely the decline is unrelated to the realignment. Habitat assessments were performed at all sites, using the methods described in the EPA Rapid Bioassessment Protocols (Barbour et al., 1999). Scores ranged from 114 to 149, out of a possible 200 (Figure 2).

Fish sampling was conducted at the six Virgil Creek sites by Douglas Carlson (NYSDEC Fisheries). Methods of sampling and data analysis are contained in Appendix XII. Based on metric analysis of the fish community data, water quality generally declines from upstream to downstream, with the exception of Station 1. As plotted on Figure 2, score trends for habitat, NBI-P and fish communities generally followed one another with two exceptions: Station-A where the habitat score was much lower than the other two, and Station-1 where the fish community score was much higher than the other two.

Literature Cited:

Barbour, M.T., J. Gerritsen, B.D. Snyder and J.B. Stribling, 1999, Rapid Bioassessment protocols for use in streams and wadeable rivers: periphyton, benthic macroinvertebrates and fish, second edition. EPA 841-B-99-002. U.S. Environmental Protection Agency; Office of Water: Washington, D.C.

Bode, R. W., M. A. Novak, L. E. Abele, D. L. Heitzman and A. J. Smith, 2002, Quality assurance work plan for biological stream monitoring in New York State. New York State Department of Environmental Conservation, Technical Report, 115 pages.

Bode, R. W., M. A. Novak and L. E. Abele, 1987, Biological assessment: Fall Creek and Virgil Creek. New York State Department of Environmental Conservation, Technical Report, 22 pages.

Preddice, T.L., 1975, Macroinvertebrate survey of Fall Creek. New York State Department of Environmental Conservation, Technical Report, 59 pages.

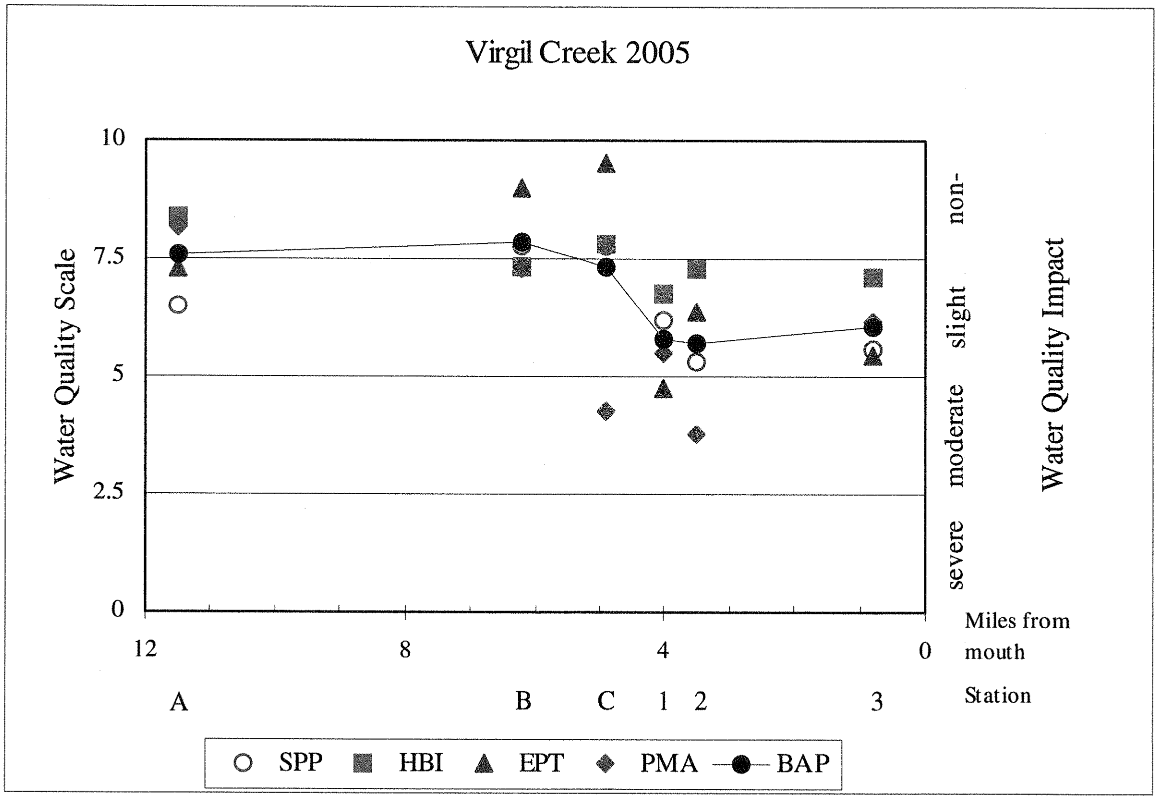
Smith, A.J., 2005, Development of a Nutrient Biotic Index for use with benthic macroinvertebrates. Masters Thesis, SUNY Albany, 70 pages.

Smith, A. J. and R. W. Bode, 2004, Analysis of variability in New York State benthic macroinvertebrate samples. New York State Department of Environmental Conservation, Technical Report, 43 pages.

Overview of field data:

On July 26, 2005, Virgil Creek at the sites sampled was 3-10 meters wide, 0.1-0.2 meter deep, and had current speeds of 50-100 cm/sec in riffles. Dissolved oxygen was 10.6- 13.0 mg/l, specific conductance was 358-503 µmhos, pH was 8.1-8.7, and the temperature was 18.3-25.8 °C (65-78 °F). Measurements for each site are found on the field data summary sheets.

Figure 1. Biological Assessment Profile (BAP) of index values, Virgil Creek, 2005 and 1987 vs. 2005. Values are plotted on a normalized scale of water quality. The line connects the mean of the four values for each site, representing species richness (SPP), EPT richness (EPT), Hilsenhoff Biotic Index (HBI), and Percent Model Affinity (PMA). See Appendix IV for more complete explanation.



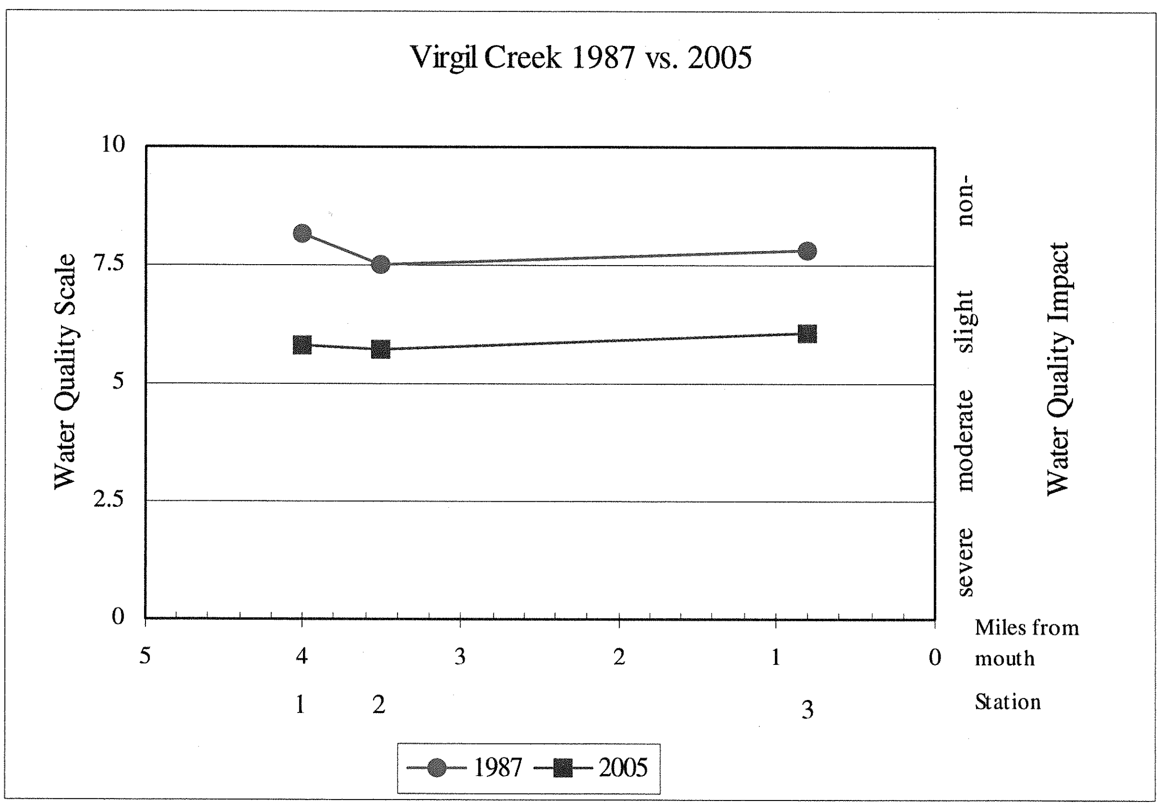


Figure 2. Nutrient Biotic Index, Fish Assessment Profile, and Habitat Scores, Virgil Creek, 2005. Scale for NBI is inverted, with higher values denoting greater nutrient enrichment. NBI-P = Nutrient Biotic Index for phosphorus, FAP = Fish Assessment Profile, HAB = Habitat Score.

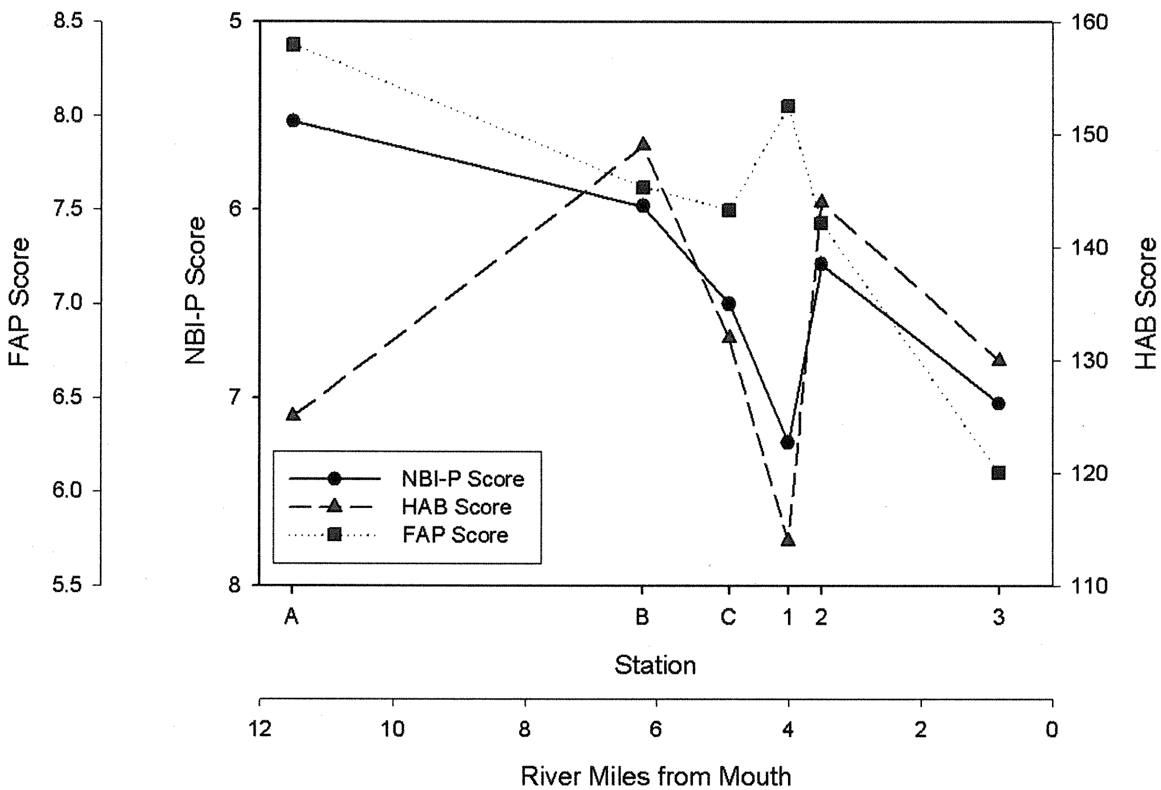


Table 1. Impact Source Determination, Virgil Creek, 2005. Numbers represent percent similarity to community type models for each impact category. Highest similarities at each station are shaded. Similarities less than 50 percent are less conclusive. Highest numbers represent probable type of impact. See Appendix X for further explanation.

	STATION					
Community Type	VIRG-A	VIRG-B	VIRG-C	VIRG-1	VIRG-2	VIRG-3
Natural: minimal human impacts	49	48	55	40	51	73
Nutrient enrichment	49	54	68	52	53	61
Toxic: industrial, municipal, or urban run-off	30	39	40	44	32	47
Organic: sewage effluent, animal wastes	22	24	33	40	50	49
Complex: municipal/industrial	28	21	34	29	47	44
Siltation	44	40	37	48	45	49
Impoundment	29	42	44	37	43	46

STATION	COMMUNITY TYPE
VIRG-A	Natural, nutrient enrichment, siltation
VIRG-B	Nutrient enrichment
VIRG-C	Nutrient enrichment
VIRG-1	Nutrient enrichment, siltation
VIRG-2	Natural, nutrient enrichment, organic
VIRG-3	Natural

TABLE 2. Station Locations for Virgil Creek, Cortland and Tompkins County, NY

STATION	LOCATION
A	Virgil, New York Above Owego Hill Road bridge Latitude/Longitude 42° 30' 07"; 76° 12' 12" 11.5 stream miles above mouth
B	Dryden, New York Above Southworth Road bridge Latitude/Longitude 42° 28' 27"; 76° 16' 23" 6.2 stream miles above mouth
C	Dryden, New York Below Lake Road bridge Latitude/Longitude 42° 29' 05"; 76° 17' 33" 4.9 stream miles above mouth
1	Dryden, New York Below Main Street bridge Latitude/Longitude 42° 29' 20"; 76° 18' 22" 4.0 stream miles above mouth
2	Dryden, New York Below Springhouse Road bridge Latitude/Longitude 42° 29' 40"; 76° 18' 50" 3.5 stream miles above mouth
3	Freeville, New York Above Johnson Road bridge Latitude/Longitude 42° 30' 21"; 76° 20' 59" 0.8 stream miles above mouth

Figure 3	Site Overview Map	Virgil Creek

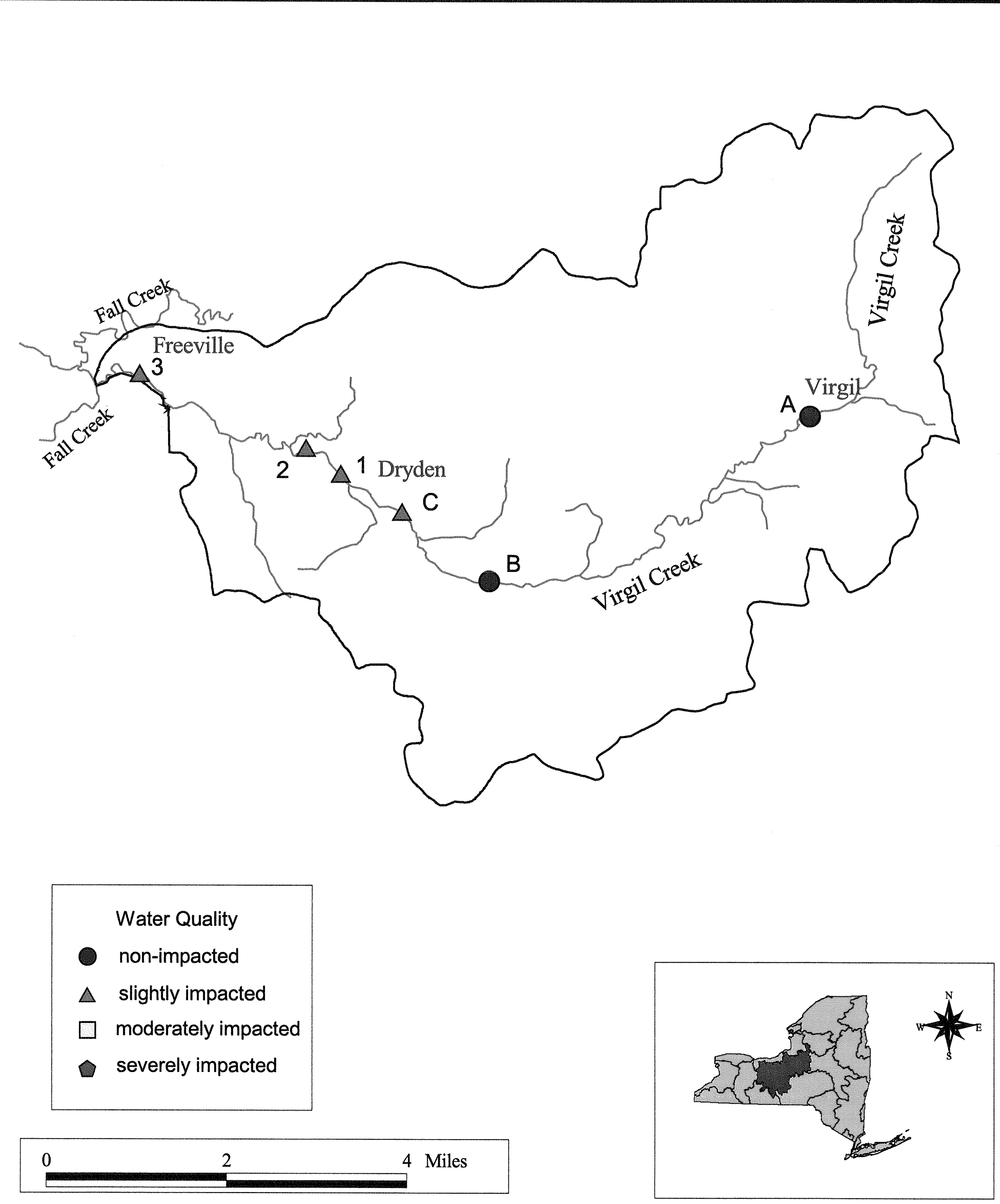


Figure 4a	Site Location Map	Virgil Creek

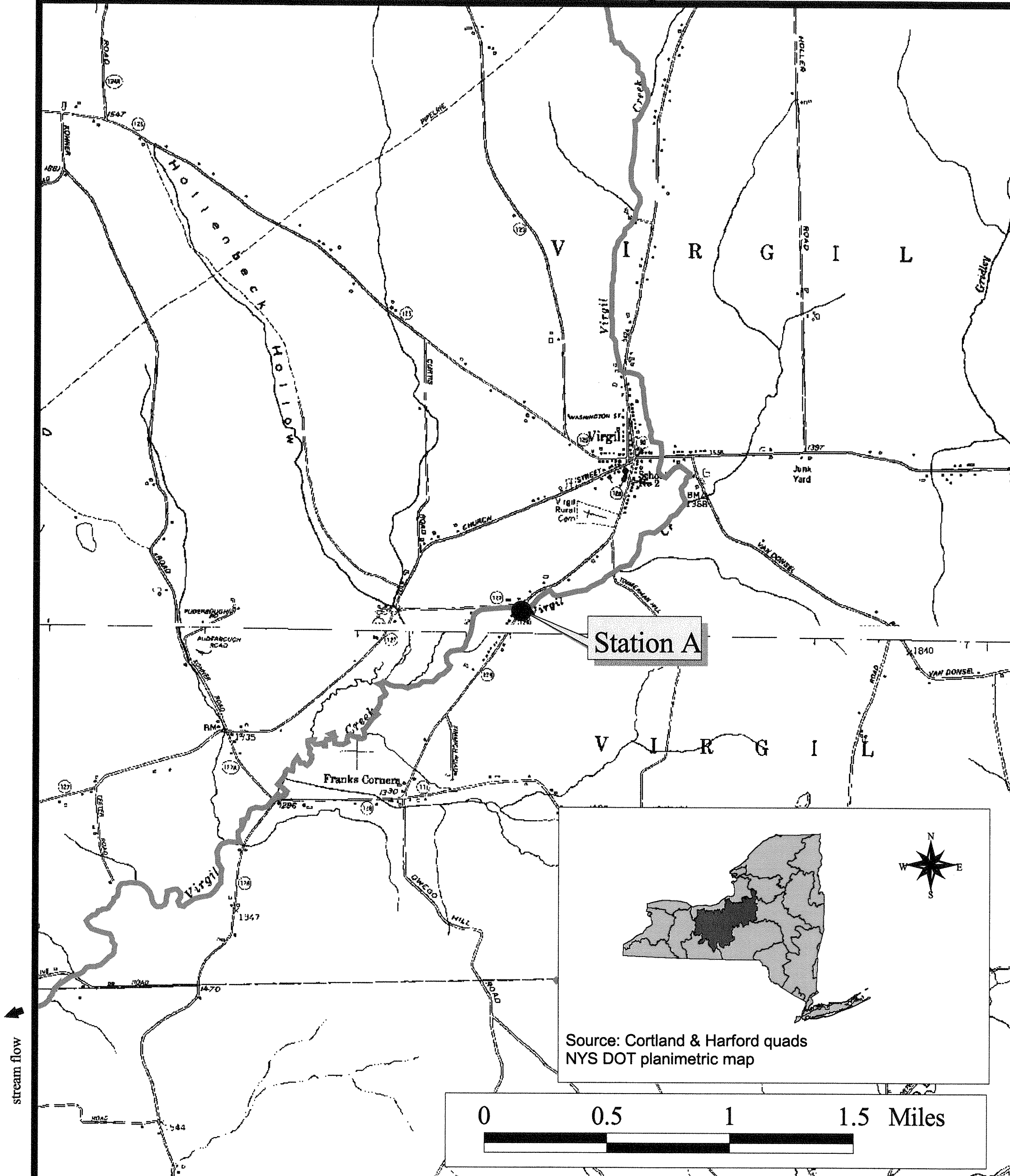


Figure 4b	Site Location Map	Virgil Creek

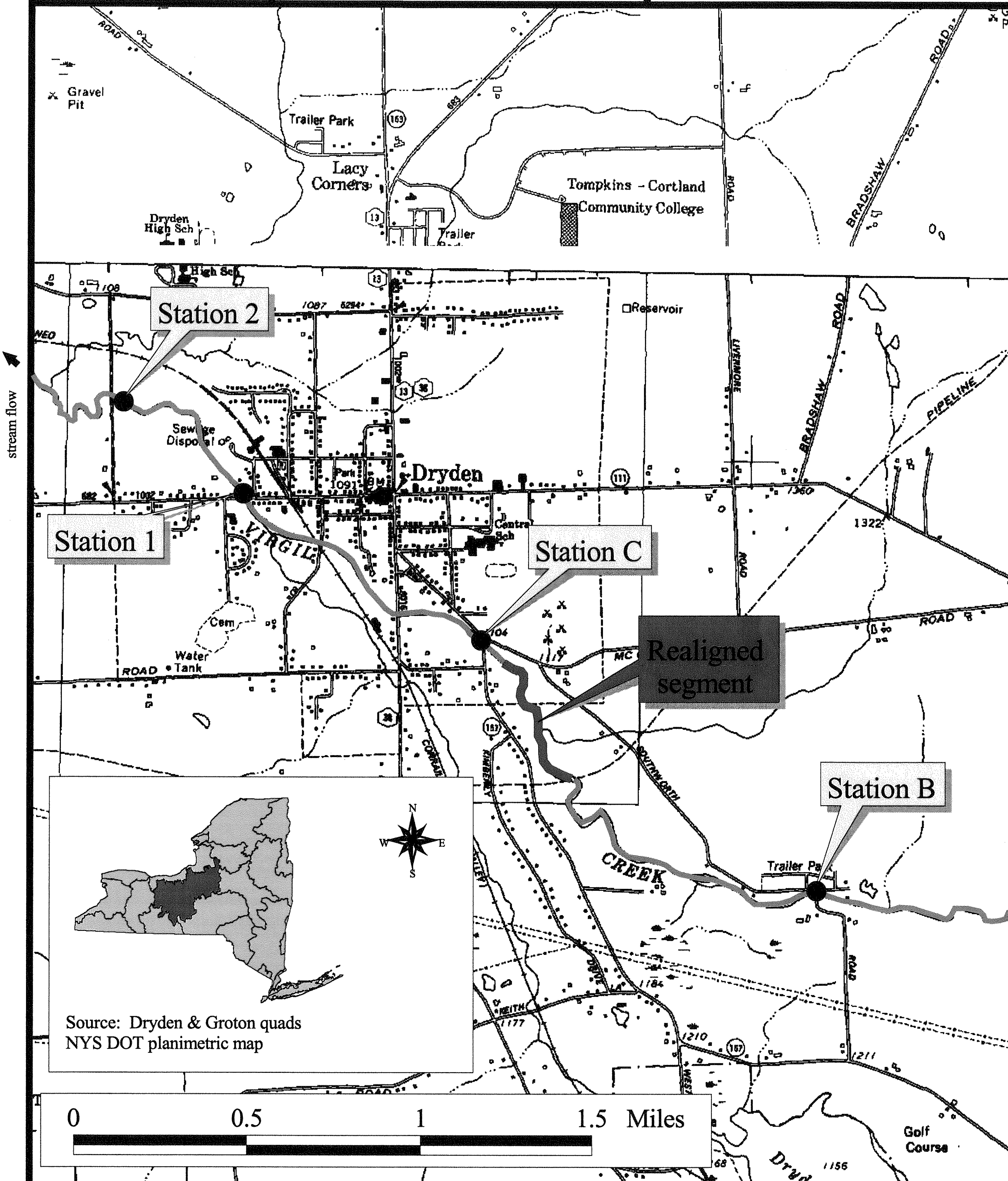


Figure 4c	Site Location Map	Virgil Creek

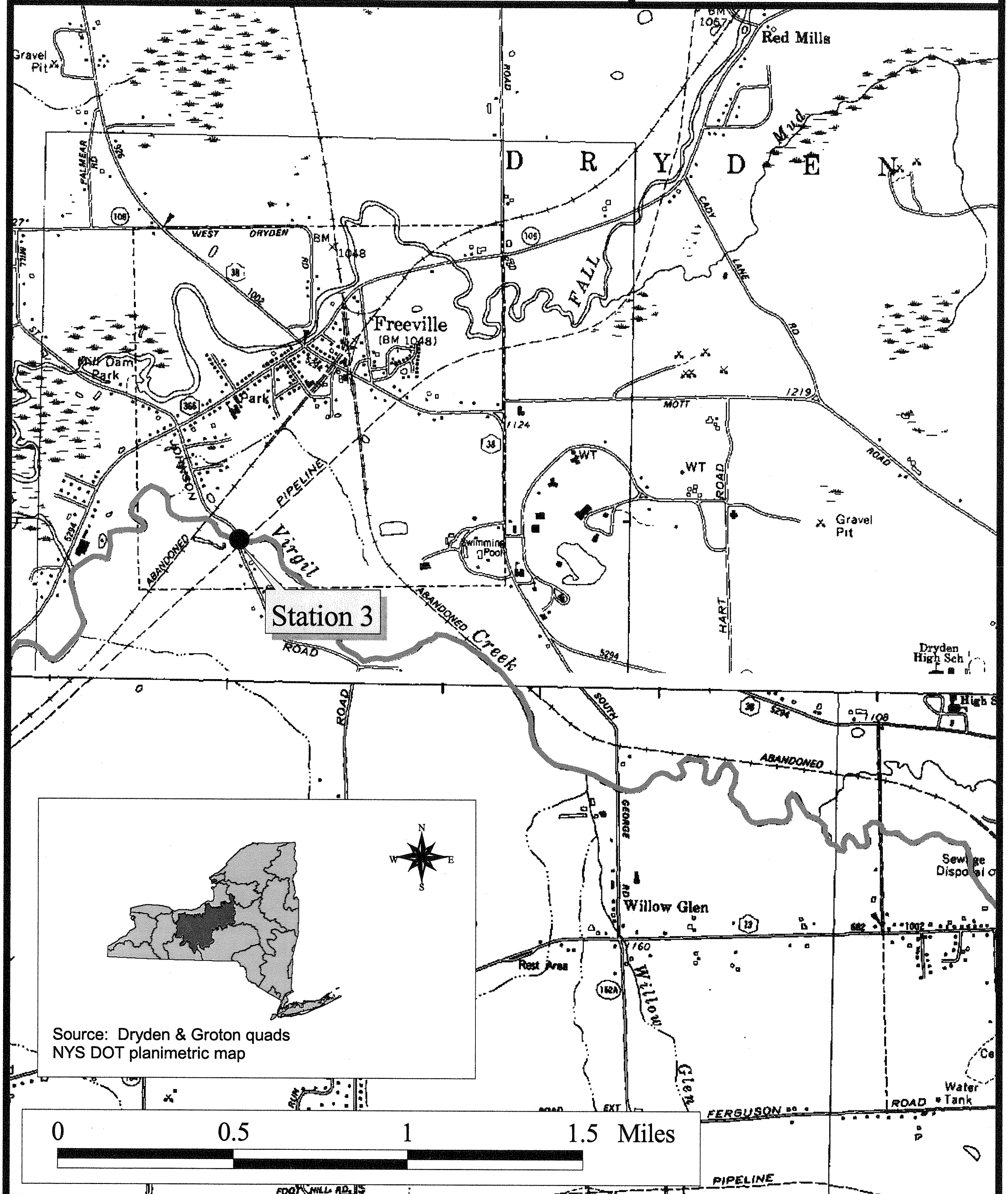


Table 3. Fish collected in Virgil Creek, 2005.

	Station						
	VIRG-A	VIRG-B	VIRG-C	VIRG-01	VIRG-02	VIRG-02	VIRG-03
	24 Aug 05	24 Aug 05	24 Aug 05	24 Aug 05	10 Aug 05	24 Aug 05	24 Aug 05
brown trout	55	52	4	1		1	
brook trout	1						
central stoneroller	10	40	20	50	40	200	700
common carp				2			
cutlip minnow	1	1	10	25	4	10	15
common shiner				2	20	25	40
spottail shiner				2	12	10	10
bluntnose minnow					2		
fathead minnow		30	30		2		
e. blacknose dace	30	60	80	50	70	80	
longnose dace	5	10	10	4	50	5	
creek chub	2		1	1		5	
fallfish			2	20	2	10	
white sucker	4	80	60	25	15	30	100
northern hog sucker			1	5		4	30
brown bullhead				1			
margined madtom							2
rock bass				2			12
pumpkinseed				8			3
smallmouth bass			3	25	2	10	30
largemouth bass				2			1
fantail darter	4	8	12	10	2	4	5
tessellated darter			20	20	12	30	50
mottled sculpin	5						
Total individuals	117	281	253	255	233	424	998
Species richness, weighted	10	8	10	10	10	10	10
% Non-tol. individuals	86	47	56	69	75	44	20
% Non-tol. species	70	63	69	79	69	79	85
Percent Model Affinity	79	66	75	74	73	54	39
Assessment Profile	8.38	7.62*	7.5	8.05	7.93**	6.93**	6.1

* The original value of 6.40 was adjusted upward by 19% based on 19% of the sample being wild trout. See Appendix XII.

** These two values were averaged to yield an overall value of 7.43

TABLE 4. Macroinvertebrate Species Collected in Virgil Creek, Cortland and Tompkins County, New York, 2005.

OLIGOCHAETA
- LUMBRICINA
  - Undetermined Lumbricina

ARTHROPODA
- INSECTA
- EPHEMEROPTERA
  - Isonychiidae
    - *Isonychia* bicolor
  - Baetidae
    - *Acentrella* sp.
    - *Baetis flavistriga*
    - *Baetis intercalaris*
  - Heptageniidae
    - *Leucrocuta sp.*
    - *Stenonema sp.*
  - Ephemerellidae
    - *Serratella deficiens*
    - Undetermined Ephemerellidae
  - Leptophlebiidae
    - *Paraleptophlebia sp.*
    - Undetermined Leptophlebiidae
  - Leptohyphidae
    - *Tricorythodes sp.*
  - Caenidae
    - *Caenis sp.*
- PLECOPTERA
  - Leuctridae
    - *Leuctra sp.*
    - Undetermined Leuctridae
  - Perlidae
    - *Agnetina capitata*
    - *Neoperla sp.*
    - *Paragnetina media*
- COLEOPTERA
  - Psephenidae
    - *Psephenus herricki*
  - Gyrinidae
    - *Dineutus sp.*
  - Elmidae
    - *Dubiraphia bivittata*
    - *Dubiraphia quadrinotata*
    - *Dubiraphia vittata*
    - *Dubiraphia sp.*
    - *Optioservus fastiditus*
    - *Optioservus trivittatus*
    - *Promoresia elegans*
    - *Stenelmis crenata*
- MEGALOPTERA
  - Corydalidae
    - *Nigronia serricornis*
- TRICHOPTERA
  - Philopotamidae
    - *Chimarra sp.*
    - *Dolophilodes sp.*
  - Hydropsychidae
    - *Cheumatopsyche sp.*
    - *Hydropsyche bronta*
    - *Hydropsyche morosa*
    - *Hydropsyche slossonae*
    - *Hydropsyche sparna*
  - Rhyacophilidae
    - *Rhyacophila fuscula*
    - *Rhyacophila sp.*
  - Hydroptilidae
    - *Hydroptila sp.*
  - Helicopsychidae
    - *Helicopsyche borealis*
- DIPTERA
  - Tipulidae
    - *Antocha sp.*
    - *Dicranota sp.*
    - *Hexatoma sp.*
    - *Tipula sp.*
  - Athericidae
    - *Atherix sp.*
  - Ceratopogonidae
    - Undetermined Ceratopogonidae
  - Empididae
    - *Hemerodromia sp.*
  - Chironomidae
    - *Thienemannimyia* gr. spp.
    - *Pagastia orthogonia*
    - *Potthastia gaedii*
    - *Sympotthastia sp.*
    - *Cardiocladius albiplumus*
    - *Cardiocladius obscurus*
    - *Cricotopus bicinctus*
    - *Cricotopus tremulus*
    - *Cricotopus trifascia gr.*
    - *Cricotopus vierriensis*
    - *Eukiefferiella devonica gr.*
    - *Paratrichocladius sp.*
    - *Rheocricotopus robacki*
    - *Tvetenia vitracies*
    - *Microtendipes pedellus gr.*
    - *Polypedilum aviceps*
    - *Polypedilum flavum*
    - *Polypedilum tuberculum*
    - *Cladotanytarsus sp.*
    - *Rheotanytarsus exiguus gr.*
    - *Sublettea coffmani*
    - *Tanytarsus guerlus* gr.

Macroinvertebrate Data Reports: Raw Data

STREAM SITE:	Virgil Creek, Station VIRG-A
LOCATION:	Virgil, New York, above Owego Hill Road bridge
DATE:	26 July 2005
SAMPLE TYPE:	Kick sample
SUBSAMPLE:	100 organisms

ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Baetidae	*Baetis flavistriga*	6
	Heptageniidae	*Leucrocuta sp.*	1
		Stenonema sp.	1
	Leptophlebiidae	*Paraleptophlebia sp.*	3
	Leptohyphidae	*Tricorythodes sp.*	12
PLECOPTERA	Leuctridae	*Leuctra sp.*	8
	Perlidae	*Agnetina capitata*	1
COLEOPTERA	Elmidae	*Optioservus fastiditus*	23
		Optioservus trivittatus	2
TRICHOPTERA	Philopotamidae	*Chimarra sp.*	1
	Hydropsychidae	*Hydropsyche slossonae*	16
	Hydroptilidae	*Hydroptila sp.*	3
DIPTERA	Tipulidae	*Antocha sp.*	1
		Dicranota sp.	1
		Hexatoma sp.	1
		Tipula sp.	1
	Ceratopogonidae	Undetermined Ceratopogonidae	1
	Chironomidae	*Thienemannimyia gr. spp.*	5
		Pagastia orthogonia	5
		Cricotopus vierriensis	2
		Microtendipes pedellus gr.	1
		Polypedilum aviceps	4
		Rheotanytarsus exiguus gr.	1

SPECIES RICHNESS:	23 (good)
BIOTIC INDEX:	3.64 (very good)
EPT RICHNESS:	10 (good)
MODEL AFFINITY:	71 (very good)
ASSESSMENT:	non-impacted (7.57)
NUTRIENT BI NBI-P	5.53 (mesotrophic)

DESCRIPTION: The kick sample was taken 20 meters upstream of the Owego Hill Road bridge in Virgil. The stream was narrow and slow-moving, with low canopy and a rubble/gravel/sand substrate. Most rocks were covered with sand cases of the midge *Rheotanytarus*, although few of these ended up in the sample. Mayflies, riffle, beetles, and caddisflies dominated the sample, and water quality was assessed as non-impacted based on the four metrics.

STREAM SITE: Virgil Creek, Station VIRG-B
LOCATION: Dryden, New York, above Southworth Road bridge
DATE: 26 July 2005
SAMPLE TYPE: Kick sample
SUBSAMPLE: 100 organisms

ARTHROPODA
INSECTA

EPHEMEROPTERA	Isonychiidae	*Isonychia bicolor*	1
	Baetidae	*Acentrella sp.*	1
		Baetis flavistriga	7
		Baetis intercalaris	1
	Leptophlebiidae	Undetermined Leptophlebiidae	1
	Leptohyphidae	*Tricorythodes sp.*	2
	Caenidae	*Caenis sp.*	8
PLECOPTERA	Perlidae	*Agnetina capitata*	8
		Neoperla sp.	2
COLEOPTERA	Psephenidae	*Psephenus herricki*	2
	Elmidae	*Dubiraphia sp.*	1
		Optioservus fastiditus	6
		Optioservus trivittatus	1
		Stenelmis crenata	32
TRICHOPTERA	Philopotamidae	*Chimarra sp.*	1
		Dolophilodes sp.	1
	Hydropsychidae	*Hydropsyche bronta*	4
	Rhyacophilidae	*Rhyacophila fuscula*	1
DIPTERA	Tipulidae	*Hexatoma sp.*	1
	Ceratopogonidae	Undetermined Ceratopogonidae	1
	Empididae	*Hemerodromia sp.*	2
	Chironomidae	*Thienemannimyia gr. spp.*	10
		Sympotthastia sp.	1
		Cricotopus vierriensis	1
		Rheocricotopus robacki	1
		Microtendipes pedellus gr.	2
		Tanytarsus guerlus gr.	1

SPECIES RICHNESS: 27 (very good)
BIOTIC INDEX: 4.63 (good)
EPT RICHNESS: 13 (very good)
MODEL AFFINITY: 63 (good)
ASSESSMENT: non-impacted (7.85)
NUTRIENT BI NBI-P 5.99 (mesotrophic)

DESCRIPTION: The macroinvertebrate community was dominated by algal-feeding riffle beetles, reflecting nutrient enrichment. Clean-water mayflies, stoneflies, and caddisflies were also numerous, and water quality was assessed as non-impacted.

STREAM SITE:	Virgil Creek, Station VIRG-C
LOCATION:	Dryden, New York, below Lake Road bridge
DATE:	26 July 2005
SAMPLE TYPE:	Kick sample
SUBSAMPLE:	100 organisms

ANNELIDA			
OLIGOCHAETA			
LUMBRICIDA		Undetermined Lumbricina	1
ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Baetidae	*Acentrella sp.*	3
		Baetis flavistriga	2
	Leptophlebiidae	Undetermined Leptophlebiidae	2
	Caenidae	*Caenis sp.*	2
PLECOPTERA	Leuctridae	Undetermined Leuctridae	1
	Perlidae	*Agnetina capitata*	2
		Paragnetina media	1
COLEOPTERA	Psephenidae	*Psephenus herricki*	4
	Elmidae	*Dubiraphia bivittata*	1
		Optioservus fastiditus	18
		Promoresia elegans	5
		Stenelmis crenata	21
TRICHOPTERA	Philopotamidae	*Dolophilodes sp.*	7
	Hydropsychidae	*Cheumatopsyche sp.*	1
		Hydropsyche bronta	13
		Hydropsyche slossonae	1
		Hydropsyche sparna	2
	Rhyacophilidae	*Rhyacophila fuscula*	1
	Helicopsychidae	*Helicopsyche borealis*	1
DIPTERA	Tipulidae	*Antocha sp.*	1
	Athericidae	*Atherix sp.*	2
	Empididae	*Hemerodromia sp.*	1
	Chironomidae	*Thienemannimyia gr. spp.*	1
		Sympotthastia sp.	1
		Tvetenia vitracies	1
		Microtendipes pedellus gr.	4

SPECIES RICHNESS:	27 (very good)
BIOTIC INDEX:	4.19 (very good)
EPT RICHNESS:	14 (very good)
MODEL AFFINITY:	45 (poor)
ASSESSMENT:	slightly impacted (7.34)
NUTRIENT BI NBI-P	6.51 (eutrophic)

DESCRIPTION: The macroinvertebrate community was dominated by algal-feeding riffle beetles, as at Station-B, but fewer mayflies were present and water quality was assessed as slightly impacted. This change was likely caused by nutrient enrichment, as reflected by a NBI-P value in the eutrophic range.

Macroinvertebrate Data Reports: Raw Data, cont'd

STREAM SITE:	Virgil Creek, Station VIRG-01
LOCATION:	Dryden, New York, below Main Street bridge
DATE:	26 July 2005
SAMPLE TYPE:	Kick sample
SUBSAMPLE:	100 organisms

ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Baetidae	*Baetis flavistriga*	1
	Ephemerellidae	*Serratella deficiens*	1
COLEOPTERA	Elmidae	*Dubiraphia quadrinotata*	1
		Optioservus trivittatus	10
		Stenelmis crenata	15
TRICHOPTERA	Hydropsychidae	*Hydropsyche morosa*	9
		Hydropsyche sparna	5
	Rhyacophilidae	*Rhyacophila sp.*	1
DIPTERA	Tipulidae	*Antocha sp.*	3
	Athericidae	*Atherix sp.*	18
	Chironomidae	*Thienemannimyia gr. spp.*	2
		Cardiocladius obscurus	4
		Cricotopus bicinctus	5
		Cricotopus tremulus gr.	3
		Cricotopus trifascia gr.	13
		Cricotopus vierriensis	1
		Eukiefferiella devonica gr.	1
		Paratrichocladius sp.	1
		Tvetenia vitracies	1
		Polypedilum flavum	2
		Rheotanytarsus exiguus gr.	1
		Tanytarsus guerlus gr.	2

SPECIES RICHNESS:	22 (good)
BIOTIC INDEX:	5.09 (good)
EPT RICHNESS:	5 (poor)
MODEL AFFINITY:	52 (good)
ASSESSMENT:	slightly impacted (5.79)
NUTRIENT BI NBI-P	7.24 (eutrophic)

DESCRIPTION: The sample was taken 40 meters upstream of the Main Street bridge in Dryden. Stream bottom rocks were covered with silt and algae, and the NBI-P denoted eutrophic conditions. Very few mayflies were present in the sample and water quality was assessed as slightly impacted.

Macroinvertebrate Data Reports: Raw Data, cont'd

STREAM SITE:	Virgil Creek, Station VIRG-02
LOCATION:	Dryden, New York, below Springhouse Road bridge
DATE:	26 July 2005
SAMPLE TYPE:	Kick sample
SUBSAMPLE:	100 organisms

ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Baetidae	*Baetis flavistriga*	1
	Heptageniidae	*Stenonema sp.*	1
	Ephemerellidae	Undetermined Ephemerellidae	3
	Caenidae	*Caenis sp.*	1
PLECOPTERA	Perlidae	*Agnetina capitata*	4
COLEOPTERA	Psephenidae	*Psephenus herricki*	2
	Gyrinidae	*Dineutus sp.*	1
	Elmidae	*Dubiraphia vittata*	1
		Optioservus trivittatus	24
		Stenelmis crenata	12
MEGALOPTERA	Corydalidae	*Nigronia serricornis*	2
TRICHOPTERA	Hydropsychidae	*Cheumatopsyche sp.*	4
		Hydropsyche morosa	27
		Hydropsyche sparna	5
DIPTERA	Tipulidae	*Antocha sp.*	2
		Tipula sp.	1
	Athericidae	*Atherix sp.*	7
	Chironomidae	*Potthastia gaedii gr.*	1
		Polypedilum flavum	1

SPECIES RICHNESS:	19 (good)
BIOTIC INDEX:	4.69 (good)
EPT RICHNESS:	8 (good)
MODEL AFFINITY:	42 (poor)
ASSESSMENT:	slightly impacted (5.68)
NUTRIENT BI NBI-P	6.29 (eutrophic)

DESCRIPTION: The stream bottom was covered with algae, as at Station-1, and the NBI-P indicated eutrophic conditions. The pH was 8.7, likely reflecting effects of heavy photosynthesis. Water quality was assessed as slightly impacted.

STREAM SITE:	Virgil Creek, Station VIRG-03
LOCATION:	Freeville, New York, above Johnson Road bridge
DATE:	26 July 2005
SAMPLE TYPE:	Kick sample
SUBSAMPLE:	100 organisms

ARTHROPODA			
INSECTA			
EPHEMEROPTERA	Baetidae	*Baetis flavistriga*	2
		Baetis intercalaris	3
	Heptageniidae	*Stenonema sp.*	4
	Ephemerellidae	*Serratella deficiens*	5
COLEOPTERA	Psephenidae	*Psephenus herricki*	1
	Elmidae	*Optioservus trivittatus*	24
		Promoresia elegans	1
		Stenelmis crenata	9
TRICHOPTERA	Hydropsychidae	*Cheumatopsyche sp.*	1
		Hydropsyche bronta	22
DIPTERA	Ceratopogonidae	Undetermined Ceratopogonidae	1
	Athericidae	*Atherix sp.*	1
	Chironomidae	*Thienemannimyia gr. spp.*	2
		Cardiocladius albiplumus	1
		Cricotopus trifascia gr.	3
		Tvetenia vitracies	10
		Polypedilum flavum	7
		Polypedilum tuberculum	1
		Cladotanytarsus sp.	1
		Sublettea coffmani	1

SPECIES RICHNESS:	20 (good)
BIOTIC INDEX:	4.81 (good)
EPT RICHNESS:	6 (good)
MODEL AFFINITY:	56 (good)
ASSESSMENT:	slightly impacted (6.07)
NUTRIENT BI NBI-P	7.03 (eutrophic)

DESCRIPTION: The site was dominated by abundant macrophytes, which were not noted at upstream sites. The macroinvertebrate community was dominated by mayflies, riffle beetles, and caddisflies, and water quality was assessed as slightly impacted. ISD and the NBI both denoted nutrient enrichment.

LABORATORY DATA SUMMARY

STREAM NAME: Virgil Creek	**DRAINAGE: 07**
DATE SAMPLED: 07/26/2005	**COUNTY: Cayuga & Tompkins**
SAMPLING METHOD: Travelling Kick	

STATION	A	B	C	01
LOCATION	Virgil	Dryden Southworth Rd	Dryden Lake Rd	Dryden Main St, Rte 13
DOMINANT SPECIES/%CONTRIBUTION/TOLERANCE/COMMON NAME				
1.	Optioservus fastiditus	Stenelmis crenata	Stenelmis crenata	Atherix sp.
	23%	32 %	21 %	18%
	intolerant	facultative	facultative	intolerant
	beetle	beetle	beetle	crane fly
2.	Hydropsyche slossonae	Thienemannimyia gr. spp.	Optioservus fastiditus	Stenelmis crenata
Intolerant = not tolerant of poor	16 %	10 %	18%	15 %
water quality	facultative	facultative	intolerant	facultative
	caddisfly	midge	beetle	beetle
3.	Tricorythodes sp.	Caenis sp.	Hydropsyche bronta	Cricotopus trifascia gr.
Facultative = occurring over a	12 %	8 %	13 %	13 %
wide range of water quality	intolerant	intolerant	facultative	tolerant
	mayfly	mayfly	caddisfly	midge
4.	Leuctra sp.	Agnetina capitata	Dolophilodes sp.	Optioservus trivittatus
Tolerant = tolerant of poor	8 %	8 %	7%	10%
water quality	intolerant	intolerant	intolerant	intolerant
	stone fly	stone fly	caddisfly	beetle
5.	Baetis flavistriga	Baetis flavistriga	Promoresia elegans	Hydropsyche morosa
	6 %	7 %	5 %	9 %
	intolerant	intolerant	intolerant	facultative
	mayfly	mayfly	beetle	caddisfly
% CONTRIBUTION OF MAJOR GROUPS (NUMBER OF TAXA IN PARENTHESES)				
Chironomidae (midges)	18.0 (6.0)	16.0 (6.0)	7.0 (4.0)	36.0 (12.0)
Trichoptera (caddisflies)	20.0 (3.0)	7.0 (4.0)	26.0 (7.0)	15.0 (3.0)
Ephemeroptera (mayflies)	23.0 (5.0)	21.0 (7.0)	9.0 (4.0)	2.0 (2.0)
Plecoptera (stoneflies)	9.0 (2.0)	10.0 (2.0)	4.0 (3.0)	0.0 (0.0)
Coleoptera (beetles)	25.0 (2.0)	42.0 (5.0)	49.0 (5.0)	26.0 (3.0)
Oligochaeta (worms)	0.0 (0.0)	0.0 (0.0)	1.0 (1.0)	0.0 (0.0)
Mollusca (clams and snails)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Crustacea (crayfish, scuds, sowbugs)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Other insects (odonates, diptera)	5.0 (5.0)	4.0 (3.0)	4.0 (3.0)	21.0 (2.0)
Other (Nemertea, Platyhelminthes)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
SPECIES RICHNESS	23	27	27	22
BIOTIC INDEX	3.64	4.63	4.19	5.09
EPT RICHNESS	10	13	14	5
PERCENT MODEL AFFINITY	71	63	45	52
FIELD ASSESSMENT	Very good	Very good	Very good	Very good
OVERALL ASSESSMENT	Non-impacted	Non-impacted	Slight	Slight

LABORATORY DATA SUMMARY

STREAM NAME: Virgil Creek		**DRAINAGE: 07**		
DATE SAMPLED: 07/26/2005		**COUNTY: Cayuga & Tompkins**		
SAMPLING METHOD: Travelling Kick				
STATION	02	03		
LOCATION	Dryden, Below STP	Freeville		
DOMINANT SPECIES/%CONTRIBUTION/TOLERANCE/COMMON NAME				
1.	Hydropsyche morosa	Optioservus trivittatus		
	27 %	24%		
	facultative	intolerant		
	caddisfly	beetle		
2.	Optioservus trivittatus	Hydropsyche bronta		
Intolerant = not tolerant of poor	24%	22 %		
water quality	intolerant	facultative		
	beetle	caddisfly		
3.	Stenelmis crenata	Tvetenia vitracies		
Facultative = occurring over a	12 %	10 %		
wide range of water quality	facultative	facultative		
	beetle	midge		
4.	Atherix sp.	Stenelmis crenata		
Tolerant = tolerant of poor	7%	9 %		
water quality	intolerant	facultative		
	crane fly	beetle		
5.	Hydropsyche sparna	Polypedilum flavum		
	5 %	7 %		
	facultative	facultative		
	caddisfly	midge		
% CONTRIBUTION OF MAJOR GROUPS (NUMBER OF TAXA IN PARENTHESES)				
Chironomidae (midges)	2.0 (2.0)	26.0 (8.0)		
Trichoptera (caddisflies)	36.0 (3.0)	23.0 (2.0)		
Ephemeroptera (mayflies)	6.0 (4.0)	14.0 (4.0)		
Plecoptera (stoneflies)	4.0 (1.0)	0.0 (0.0)		
Coleoptera (beetles)	40.0 (5.0)	35.0 (4.0)		
Oligochaeta (worms)	0.0 (0.0)	0.0 (0.0)		
Mollusca (clams and snails)	0.0 (0.0)	0.0 (0.0)		
Crustacea (crayfish, scuds, sowbugs)	0.0 (0.0)	0.0 (0.0)		
Other insects (odonates, diptera)	12.0 (4.0)	2.0 (2.0)		
Other (Nemertea, Platyhelminthes)	0.0 (0.0)	0.0 (0.0)		
SPECIES RICHNESS	19	20		
BIOTIC INDEX	4.69	4.81		
EPT RICHNESS	8	6		
PERCENT MODEL AFFINITY	42	56		
FIELD ASSESSMENT	Very good	Very good		
OVERALL ASSESSMENT	Slight	Slight		

FIELD DATA SUMMARY

STREAM NAME: Virgil Creek		DATE SAMPLED: 7/26/2005		
REACH: Virgil to Freeville				
FIELD PERSONNEL INVOLVED: Bode, Heitzman				
STATION	A	B	C	01
ARRIVAL TIME AT STATION	11:05 AM	11:40 AM	12:20 PM	1:00 PM
LOCATION	Virgil	Dryden Southworth Rd	Dryden Lake Rd	Dryden Main St, Rte 13
PHYSICAL CHARACTERISTICS				
Width (meters)	3.0	8.0	3.0	10
Depth (meters)	0.1	0.1	0.2	0.1
Current speed (cm per sec.)	50	75	100	100
Substrate (%)				
Rock (>25.4 cm, or bedrock)	10	10	10	10
Rubble (6.35 – 25.4 cm)	40	30	30	30
Gravel (0.2 – 6.35 cm)	20	20	20	20
Sand (0.06 – 2.0 mm)	10	10	10	10
Silt (0.004 – 0.06 mm)	20	30	30	30
Embeddedness (%)	20	30	30	20
CHEMICAL MEASUREMENTS				
Temperature (° C)	18.3	21.5	23.9	24.3
Specific Conductance (umhos)	503	395	409	358
Dissolved Oxygen (mg/l)	12.2	10.8	10.6	10.8
pH	8.1	8.4	8.5	8.6
BIOLOGICAL ATTRIBUTES				
Canopy (%)	20	20	20	10
Aquatic Vegetation				
algae – suspended				
algae – attached, filamentous	x	x	x	x
algae – diatoms	x	x	x	x
macrophytes or moss				
Occurrence of Macroinvertebrates				
Ephemeroptera (mayflies)	x	x	x	x
Plecoptera (stoneflies)	x	x	x	x
Trichoptera (caddisflies)	x	x	x	x
Coleoptera (beetles)	x	x	x	x
Megaloptera (dobsonflies, alderflies)			x	
Odonata (dragonflies, damselflies)		x		
Chironomidae (midges)				
Simuliidae (black flies)				
Decapoda (crayfish)	x	x	x	x
Gammaridae (scuds)				
Mollusca (snails, clams)				
Oligochaeta (worms)				
Other	x	x		
FAUNAL CONDITION	Very good	Very good	Very good	Very good

FIELD DATA SUMMARY				
STREAM NAME: Virgil Creek		DATE SAMPLED: 7/26/2005		
REACH: Virgil to Freeville				
FIELD PERSONNEL INVOLVED: Bode, Heitzman				
STATION	02	03		
ARRIVAL TIME AT STATION	1:30 PM	1:55 PM		
LOCATION	Dryden, Below STP	Freeville		
PHYSICAL CHARACTERISTICS				
Width (meters)	8.0	8.0		
Depth (meters)	0.1	0.1		
Current speed (cm per sec.)	100	90		
Substrate (%)				
Rock (>25.4 cm, or bedrock)	10	10		
Rubble (6.35 – 25.4 cm)	30	30		
Gravel (0.2 – 6.35 cm)	20	20		
Sand (0.06 – 2.0 mm)	10	10		
Silt (0.004 – 0.06 mm)	30	30		
Embeddedness (%)	30	30		
CHEMICAL MEASUREMENTS				
Temperature (° C)	23.3	25.8		
Specific Conductance (umhos)	400	395		
Dissolved Oxygen (mg/l)	12.4	13.0		
pH	8.7	8.6		
BIOLOGICAL ATTRIBUTES				
Canopy (%)	30	10		
Aquatic Vegetation				
algae – suspended				
algae – attached, filamentous	x	x		
algae – diatoms	x	x		
macrophytes or moss		x		
Occurrence of Macroinvertebrates				
Ephemeroptera (mayflies)	x	x		
Plecoptera (stoneflies)	x	x		
Trichoptera (caddisflies)	x	x		
Coleoptera (beetles)	x	x		
Megaloptera (dobsonflies, alderflies)		x		
Odonata (dragonflies, damselflies)				
Chironomidae (midges)		x		
Simuliidae (black flies)				
Decapoda (crayfish)	x	x		
Gammaridae (scuds)				
Mollusca (snails, clams)				
Oligochaeta (worms)				
Other				
FAUNAL CONDITION	Very good	Very good		

Appendix I. Biological Methods for Kick Sampling

A. Rationale: The use of the standardized kick sampling method provides a biological assessment technique that lends itself to rapid assessments of stream water quality.

B. Site Selection: Sampling sites are selected based on these criteria: (1) The sampling location should be a riffle with a substrate of rubble, gravel and sand; depth should be one meter or less, and current speed should be at least 0.4 meters per second. (2) The site should have comparable current speed, substrate type, embeddedness, and canopy cover to both upstream and downstream sites to the degree possible. (3) Sites are chosen to have a safe and convenient access.

C. Sampling: Macroinvertebrates are sampled using the standardized traveling kick method. An aquatic net is positioned in the water at arms' length downstream and the stream bottom is disturbed by foot, so that organisms are dislodged and carried into the net. Sampling is continued for a specified time and distance in the stream. Rapid assessment sampling specifies sampling for five minutes over a distance of five meters. The contents of the net are emptied into a pan of stream water. The contents are then examined, and the major groups of organisms are recorded, usually on the ordinal level (e.g., stoneflies, mayflies, caddisflies). Larger rocks, sticks, and plants may be removed from the sample if organisms are first removed from them. The contents of the pan are poured into a U.S. No. 30 sieve and transferred to a quart jar. The sample is then preserved by adding 95% ethyl alcohol.

D. Sample Sorting and Subsampling: In the laboratory, the sample is rinsed with tap water in a U.S. No. 40 standard sieve to remove any fine particles left in the residues from field sieving. The sample is transferred to an enamel pan and distributed homogeneously over the bottom of the pan. A small amount of the sample is randomly removed with a spatula, rinsed with water, and placed in a petri dish. This portion is examined under a dissecting stereomicroscope and 100 organisms are randomly removed from the debris. As they are removed, they are sorted into major groups, placed in vials containing 70 percent alcohol, and counted. The total number of organisms in the sample is estimated by weighing the residue from the picked subsample and determining its proportion of the total sample weight.

E. Organism Identification: All organisms are identified to the species level whenever possible. Chironomids and oligochaetes are slide-mounted and viewed through a compound microscope; most other organisms are identified as whole specimens using a dissecting stereomicroscope. The number of individuals in each species and the total number of individuals in the subsample are recorded on a data sheet. All organisms from the subsample are archived (either slide-mounted or preserved in alcohol). If the results of the identification process are ambiguous, suspected of being spurious, or do not yield a clear water quality assessment, additional subsampling may be required.

Appendix II. Macroinvertebrate Community Parameters

1. Species Richness: is the total number of species or taxa found in the sample. For subsamples of 100-organisms each that are taken from kick samples, expected ranges in most New York State streams are: greater than 26, non-impacted; 19-26, slightly impacted; 11-18, moderately impacted; less than 11, severely impacted.

2. EPT Richness: denotes the total number of species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera) found in an average 100-organisms subsample. These are considered to be clean-water organisms, and their presence is generally correlated with good water quality (Lenat, 1987). Expected assessment ranges from most New York State streams are: greater than 10, non-impacted; 6-10, slightly impacted; 2-5, moderately impacted; and 0-1, severely impacted.

3. Hilsenhoff Biotic Index: is a measure of the tolerance of organisms in a sample to organic pollution (sewage effluent, animal wastes) and low dissolved oxygen levels. It is calculated by multiplying the number of individuals of each species by its assigned tolerance value, summing these products, and dividing by the total number of individuals. On a 0-10 scale, tolerance values range from intolerant (0) to tolerant (10). For the purpose of characterizing species' tolerance, intolerant = 0-4, facultative = 5-7, and tolerant = 8-10. Tolerance values are listed in Hilsenhoff (1987). Additional values are assigned by the NYS Stream Biomonitoring Unit. The most recent values for each species are listed in Quality Assurance document, Bode et al. (1996). Impact ranges are: 0-4.50, non-impacted; 4.51-6.50, slightly impacted; 6.51-8.50, moderately impacted; and 8.51-10.00, severely impacted.

4. Percent Model Affinity: is a measure of similarity to a model, non-impacted community based on percent abundance in seven major macroinvertebrate groups (Novak and Bode, 1992). Percent abundances in the model community are: 40% Ephemeroptera; 5% Plecoptera; 10% Trichoptera; 10% Coleoptera; 20% Chironomidae; 5% Oligochaeta; and 10% Other. Impact ranges are: greater than 64, non-impacted; 50-64, slightly impacted; 35-49, moderately impacted; and less than 35, severely impacted.

Bode, R.W., M.A. Novak, L.E. Abele, D.L. Heitzman and A.J. Smith, 2002, Quality assurance work plan for biological stream monitoring in New York State. NYSDEC Technical Report, 115 pages.

Hilsenhoff, W. L., 1987, An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20(1): 31-39.

Lenat, D. R., 1987, Water quality assessment using a new qualitative collection method for freshwater benthic macroinvertebrates. North Carolina Division of Environmental Management, Technical Report, 12 pages.

Novak, M.A. and R.W. Bode, 1992, Percent model affinity: a new measure of macroinvertebrate community composition. J. N. Am. Benthol. Soc. 11(1): 80-85.

Appendix III. Levels of Water Quality Impact in Streams

The description of overall stream water quality based on biological parameters uses a four-tiered system of classification. Level of impact is assessed for each individual parameter and then combined for all parameters to form a consensus determination. Four parameters are used: species richness, EPT richness, biotic index, and percent model affinity (see Appendix II). The consensus is based on the determination of the majority of the parameters. Since parameters measure different aspects of the macroinvertebrate community, they cannot be expected to always form unanimous assessments. The assessment ranges given for each parameter are based on subsamples of 100-organisms each that are taken from macroinvertebrate riffle kick samples. These assessments also apply to most multiplate samples, with the exception of percent model affinity.

1. *Non-impacted:* Indices reflect very good water quality. The macroinvertebrate community is diverse, usually with at least 27 species in riffle habitats. Mayflies, stoneflies, and caddisflies are well represented; EPT richness is greater than 10. The biotic index value is 4.50 or less. Percent model affinity is greater than 64. Water quality should not be limiting to fish survival or propagation. This level of water quality includes both pristine habitats and those receiving discharges which minimally alter the biota.

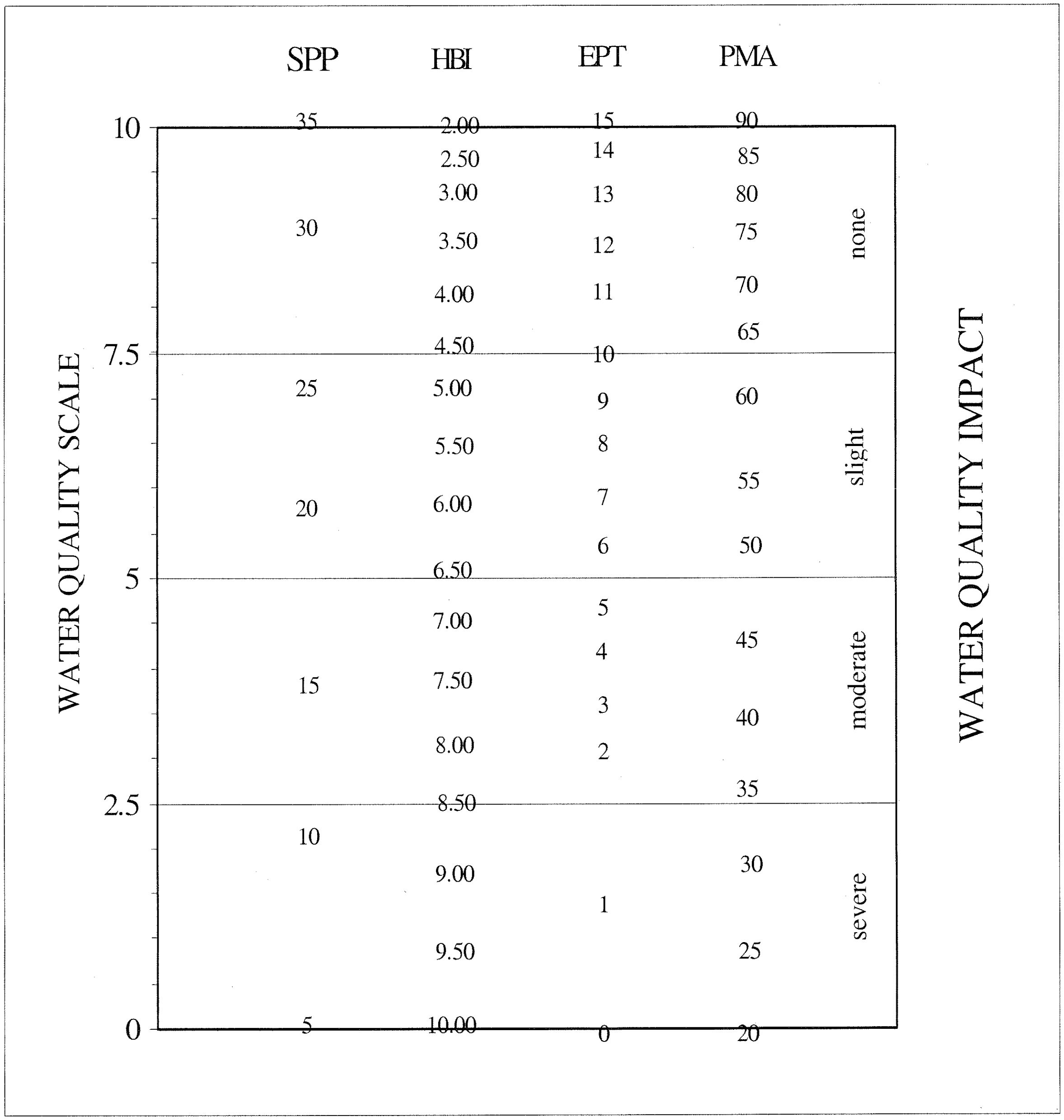
2. *Slightly impacted:* Indices reflect good water quality. The macroinvertebrate community is slightly but significantly altered from the pristine state. Species richness is usually 19-26. Mayflies and stoneflies may be restricted, with EPT richness values of 6-10. The biotic index value is 4.51-6.50. Percent model affinity is 50-64. Water quality is usually not limiting to fish survival, but may be limiting to fish propagation.

3. *Moderately impacted:* Indices reflect poor water quality. The macroinvertebrate community is altered to a large degree from the pristine state. Species richness is usually 11-18 species. Mayflies and stoneflies are rare or absent, and caddisflies are often restricted; the EPT richness is 2-5. The biotic index value is 6.51-8.50. Percent model affinity is 35-49. Water quality often is limiting to fish propagation, but usually not to fish survival.

4. *Severely impacted:* Indices reflect very poor water quality. The macroinvertebrate community is limited to a few tolerant species. Species richness is 10 or fewer. Mayflies, stoneflies and caddisflies are rare or absent; EPT richness is 0-1. The biotic index value is greater than 8.50. Percent model affinity is less than 35. The dominant species are almost all tolerant, and are usually midges and worms. Often, 1-2 species are very abundant. Water quality is often limiting to both fish propagation and fish survival.

Appendix IV-A. Biological Assessment Profile: Conversion of Index Values to a Common 10-Scale

The Biological Assessment Profile of index values, developed by Phil O'Brien, Division of Water, NYSDEC, is a method of plotting biological index values on a common scale of water quality impact. Values from the four indices defined in Appendix II are converted to a common 0-10 scale using the formulae in the Quality Assurance document (Bode et al., 2002), and as shown in the figure below.



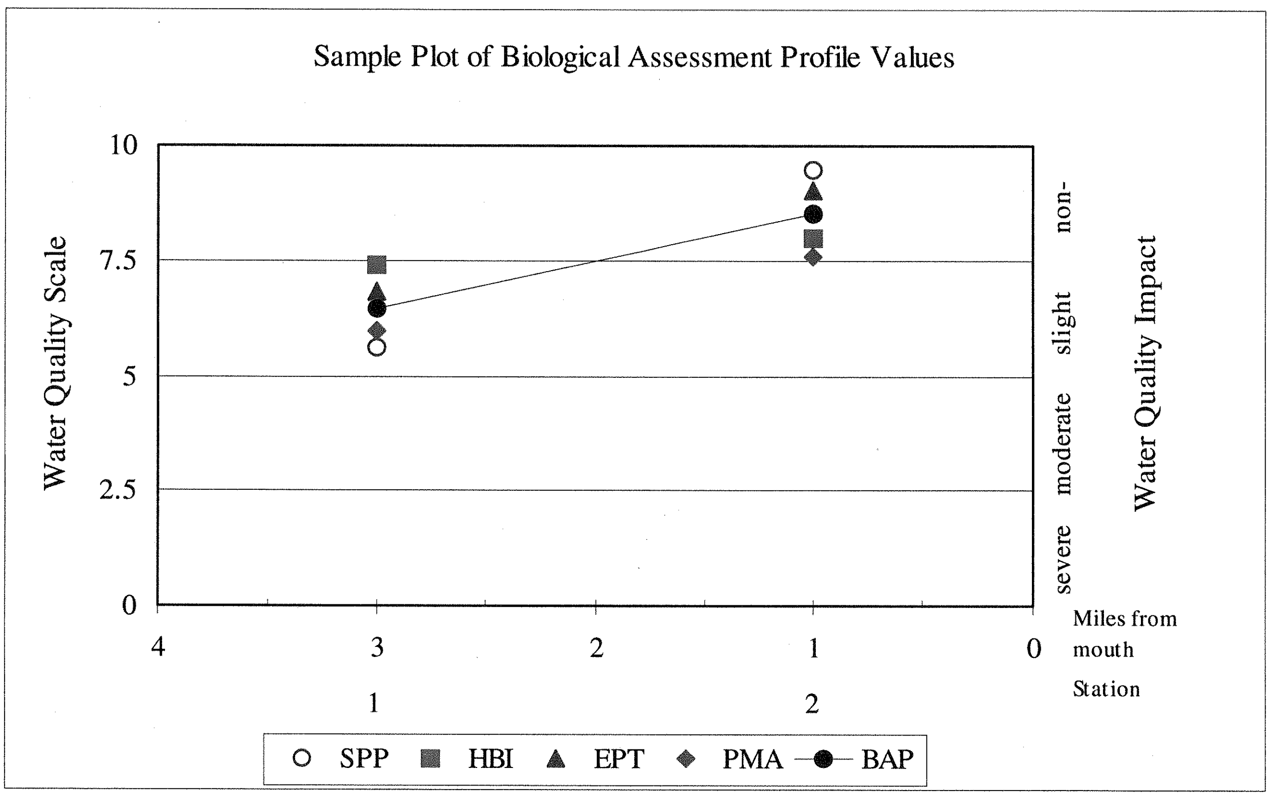
Appendix IV-B. Biological Assessment Profile: Plotting Values

To plot survey data:
1. Position each site on the x-axis according to miles or tenths of a mile upstream of the mouth.
2. Plot the values of the four indices for each site as indicated by the common scale.
3. Calculate the mean of the four values and plot the result. This represents the assessed impact for each site.

Example data:

	Station 1		Station 2	
	metric value	10-scale value	metric value	10-scale value
Species richness	20	5.59	33	9.44
Hilsenhoff biotic index	5.00	7.40	4.00	8.00
EPT richness	9	6.80	13	9.00
Percent model affinity	55	5.97	65	7.60
Average		6.44 (slight)		8.51 (non-)

Table IV-B. Sample Plot of Biological Assessment Profile values



Appendix V. Water Quality Assessment Criteria

Water Quality Assessment Criteria for Non-Navigable Flowing Waters

	Species Richness	Hilsenhoff Biotic Index	EPT Richness	Percent Model Affinity#	Species Diversity*
Non-Impacted	>26	0.00-4.50	>10	>64	>4
Slightly Impacted	19-26	4.51-6.50	6-10	50-64	3.01-4.00
Moderately Impacted	11-18	6.51-8.50	2-5	35-49	2.01-3.00
Severely Impacted	0-10	8.51-10.00	0-1	<35	0.00-2.00

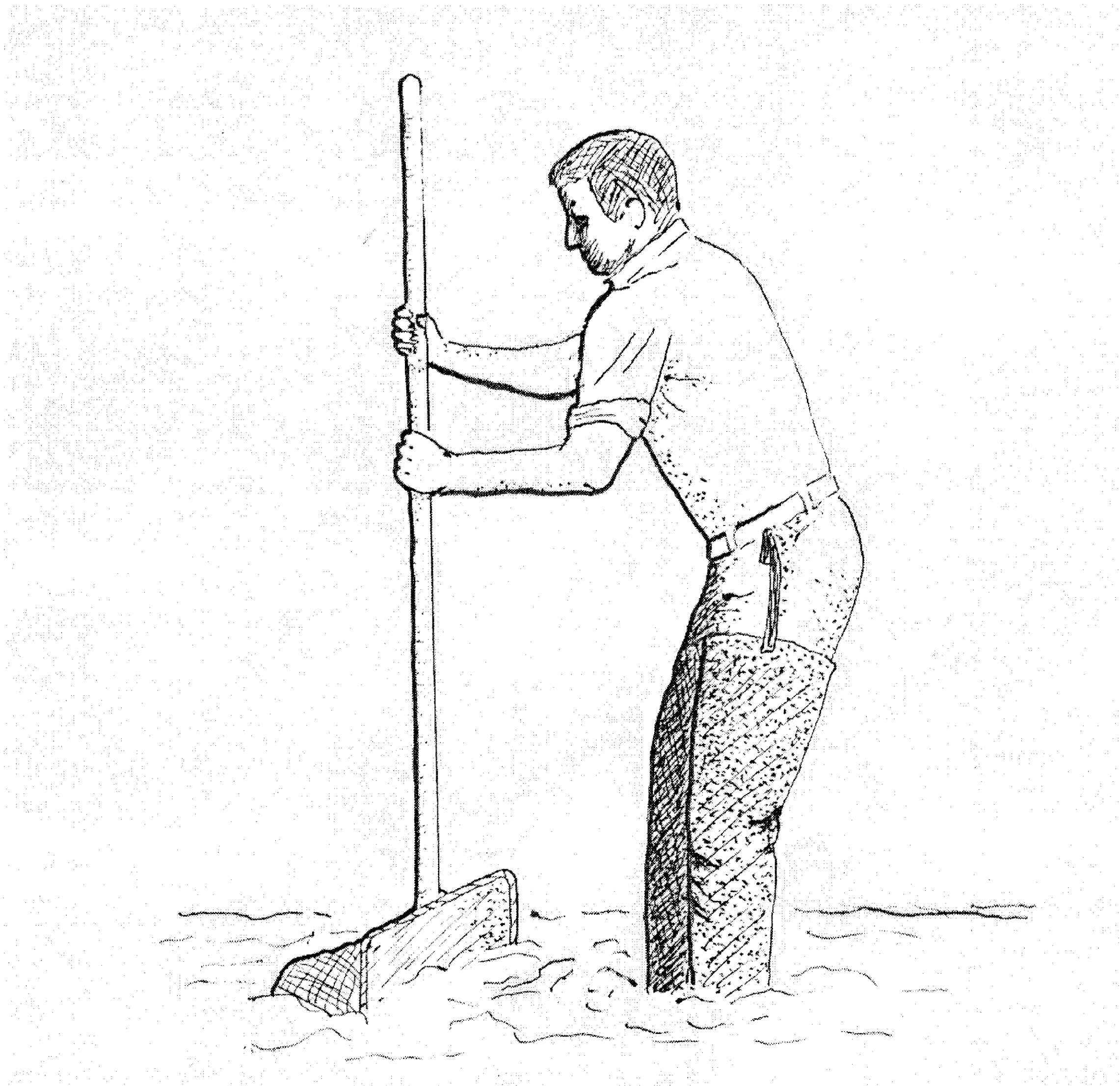
Percent model affinity criteria are used for traveling kick samples but not for multiplate samples.
* Diversity criteria are used for multiplate samples but not for traveling kick samples.

Water Quality Assessment Criteria for Navigable Flowing Waters

	Species Richness	Hilsenhoff Biotic Index	EPT Richness	Species Diversity
Non-Impacted	>21	0.00-7.00	>5	>3.00
Slightly Impacted	17-21	7.01-8.00	4-5	2.51-3.00
Moderately Impacted	12-16	8.01-9.00	2-3	2.01-2.50
Severely Impacted	0-11	9.01-10.00	0-1	0.00-2.00

Appendix VI.

The Traveling Kick Sample

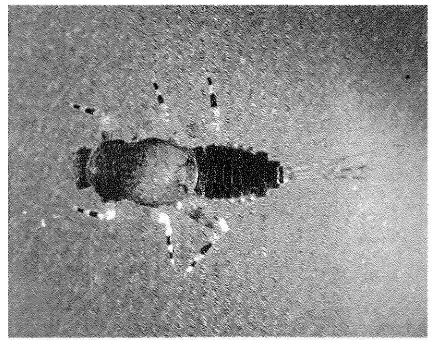


← current

Rocks and sediment in a riffle are dislodged by foot upstream of a net. Dislodged organisms are carried by the current into the net. Sampling continues for five minutes, as the sampler gradually moves downstream to cover a distance of five meters.

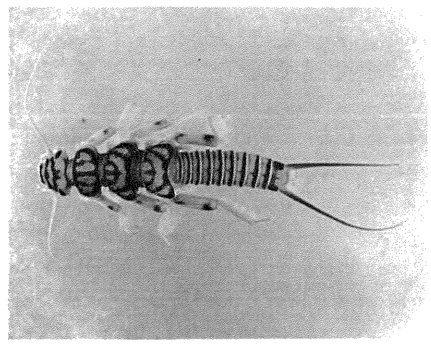
Appendix VII. A.
Aquatic Macroinvertebrates that Usually Indicate Good Water Quality

Mayfly nymphs are often the most numerous organisms found in clean streams. They are sensitive to most types of pollution, including low dissolved oxygen (less than 5 ppm), chlorine, ammonia, metals, pesticides, and acidity. Most mayflies are found clinging to the undersides of rocks.



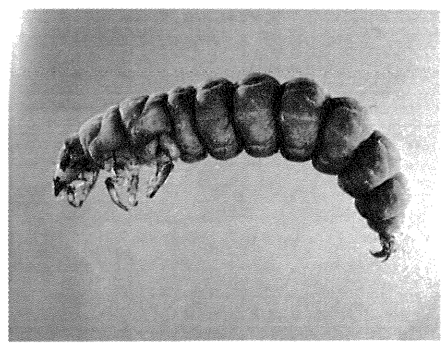
MAYFLIES

Stonefly nymphs are mostly limited to cool, well-oxygenated streams. They are sensitive to most of the same pollutants as mayflies, except acidity. They are usually much less numerous than mayflies. The presence of even a few stoneflies in a stream suggests that good water quality has been maintained for several months.



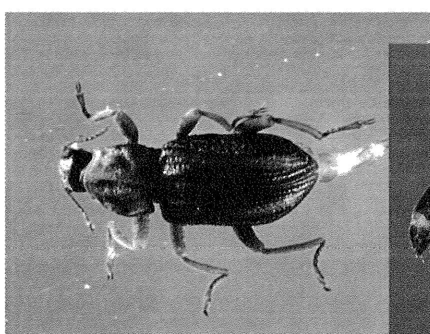
STONEFLIES

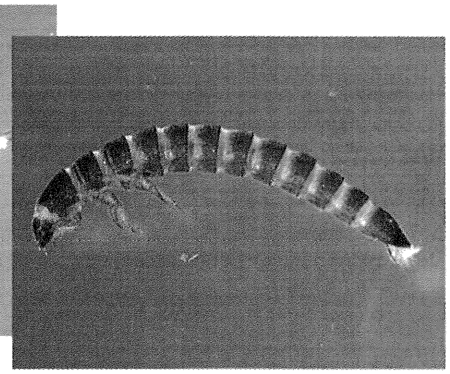
Caddisfly larvae often build a portable case of sand, stones, sticks, or other debris. Many caddisfly larvae are sensitive to pollution, although a few are tolerant. One family spins nets to catch drifting plankton, and is often numerous in nutrient-enriched stream segments.



CADDISFLIES

The most common beetles in streams are riffle beetles (adult and larva pictured) and water pennies (not shown). Most of these require a swift current and an adequate supply of oxygen, and are generally considered clean-water indicators.

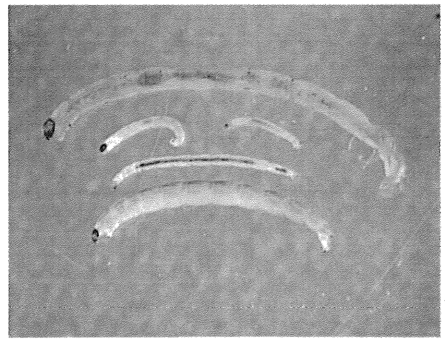




BEETLES

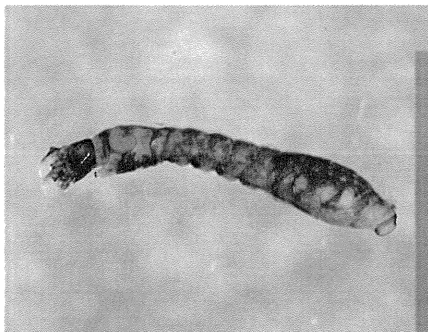
Appendix VII. B.
Aquatic Macroinvertebrates that Usually Indicate Poor Water Quality

Midges are the most common aquatic flies. The larvae occur in almost any aquatic situation. Many species are very tolerant to pollution. Large, red midge larvae called "bloodworms" indicate organic enrichment. Other midge larvae filter plankton, indicating nutrient enrichment when numerous.

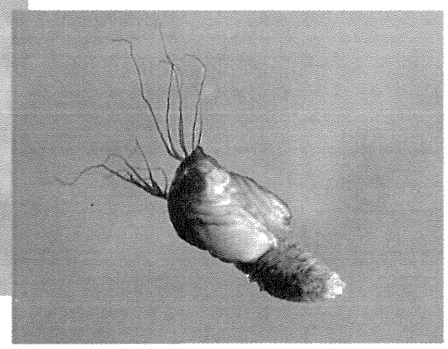


MIDGES

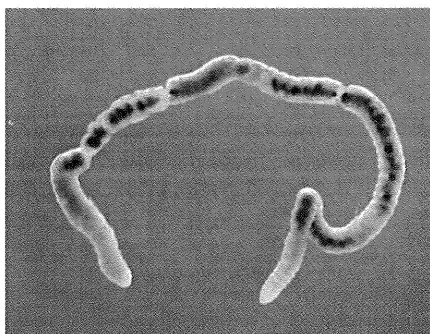
Black fly larvae have specialized structures for filtering plankton and bacteria from the water, and require a strong current. Some species are tolerant of organic enrichment and toxic contaminants, while others are intolerant of pollutants.



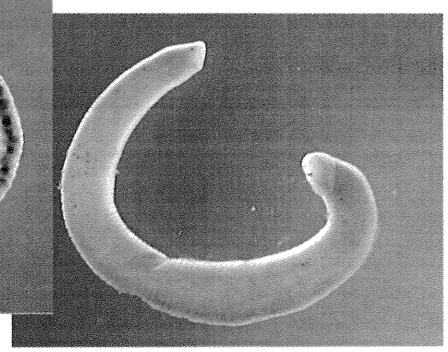
BLACK FLIES



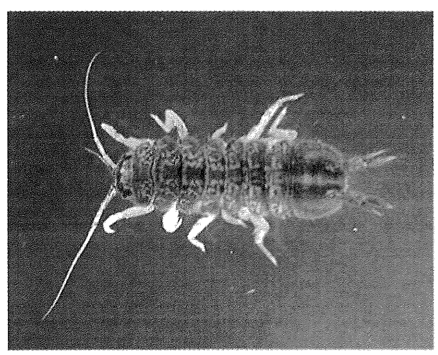
The segmented worms include the leeches and the small aquatic worms. The latter are more common, though usually unnoticed. They burrow in the substrate and feed on bacteria in the sediment. They can thrive under conditions of severe pollution and very low oxygen levels, and are thus valuable pollution indicators. Many leeches are also tolerant of poor water quality.



WORMS



Aquatic sowbugs are crustaceans that are often numerous in situations of high organic content and low oxygen levels. They are classic indicators of sewage pollution, and can also thrive in toxic situations.



SOWBUGS

Digital images by Larry Abele, New York State Department of Environmental Conservation, Stream Biomonitoring Unit.

Appendix VIII. The Rationale of Biological Monitoring

Biological monitoring refers to the use of resident benthic macroinvertebrate communities as indicators of water quality. Macroinvertebrates are larger-than-microscopic invertebrate animals that inhabit aquatic habitats; freshwater forms are primarily aquatic insects, worms, clams, snails, and crustaceans.

Concept:

Nearly all streams are inhabited by a community of benthic macroinvertebrates. The species comprising the community each occupy a distinct niche defined and limited by a set of environmental requirements. The composition of the macroinvertebrate community is thus determined by many factors, including habitat, food source, flow regime, temperature, and water quality. The community is presumed to be controlled primarily by water quality if the other factors are determined to be constant or optimal. Community components which can change with water quality include species richness, diversity, balance, abundance, and presence/absence of tolerant or intolerant species. Various indices or metrics are used to measure these community changes. Assessments of water quality are based on metric values of the community, compared to expected metric values.

Advantages:

The primary advantages to using macroinvertebrates as water quality indicators are that they:

- are sensitive to environmental impacts
- are less mobile than fish, and thus cannot avoid discharges
- can indicate effects of spills, intermittent discharges, and lapses in treatment
- are indicators of overall, integrated water quality, including synergistic effects
- are abundant in most streams and are relatively easy and inexpensive to sample
- are able to detect non-chemical impacts to the habitat, e.g. siltation or thermal changes
- are vital components of the aquatic ecosystem and important as a food source for fish
- are more readily perceived by the public as tangible indicators of water quality
- can often provide an on-site estimate of water quality
- can often be used to identify specific stresses or sources of impairment
- can be preserved and archived for decades, allowing for direct comparison of specimens
- bioaccumulate many contaminants, so that analysis of their tissues is a good monitor of toxic substances in the aquatic food chain

Limitations:

Biological monitoring is not intended to replace chemical sampling, toxicity testing, or fish surveys. Each of these measurements provides information not contained in the others. Similarly, assessments based on biological sampling should not be taken as being representative of chemical sampling. Some substances may be present in levels exceeding ambient water quality criteria, yet have no apparent adverse community impact.

Appendix IX. Glossary

anthropogenic: caused by human actions

assessment: a diagnosis or evaluation of water quality

benthos: organisms occurring on or in the bottom substrate of a waterbody

bioaccumulate: accumulate contaminants in the tissues of an organism

biomonitoring: the use of biological indicators to measure water quality

community: a group of populations of organisms interacting in a habitat

drainage basin: an area in which all water drains to a particular waterbody; watershed

electrofishing: sampling fish by using electric currents to temporarily immobilize them, allowing capture

EPT richness: the number of species of mayflies (Ephemeroptera), stoneflies (Plecoptera), and caddisflies (Trichoptera)in a sample or subsample

facultative: occurring over a wide range of water quality; neither tolerant nor intolerant of poor water quality

fauna: the animal life of a particular habitat

impact: a change in the physical, chemical, or biological condition of a waterbody

impairment: a detrimental effect caused by an impact

index: a number, metric, or parameter derived from sample data used as a measure of water quality

intolerant: unable to survive poor water quality

longitudinal trends: upstream-downstream changes in water quality in a river or stream

macroinvertebrate: a larger-than-microscopic invertebrate animal that lives at least part of its life in aquatic habitats

multiplate: multiple-plate sampler, a type of artificial substrate sampler of aquatic macroinvertebrates

organism: a living individual

PAHs: Polycyclic Aromatic Hydrocarbons, a class of organic compounds that are often toxic or carcinogenic.

rapid bioassessment: a biological diagnosis of water quality using field and laboratory analysis designed to allow assessment of water quality in a short turn-around time; usually involves kick sampling and laboratory subsampling of the sample

riffle: wadeable stretch of stream usually with a rubble bottom and sufficient current to have the water surface broken by the flow; rapids

species richness: the number of macroinvertebrate species in a sample or subsample

station: a sampling site on a waterbody

survey: a set of samplings conducted in succession along a stretch of stream

synergistic effect: an effect produced by the combination of two factors that is greater than the sum of the two factors

tolerant: able to survive poor water quality

Appendix X. Impact Source Determination Methods and Community Models

Definition: Impact Source Determination (ISD) is the procedure for identifying types of impacts that exert deleterious effects on a waterbody. While the analysis of benthic macroinvertebrate communities has been shown to be an effective means of determining severity of water quality impacts, it has been less effective in determining what kind of pollution is causing the impact. ISD uses community types or models to ascertain the primary factor influencing the fauna.

Development of methods: The method found to be most useful in differentiating impacts in New York State streams was the use of community types based on composition by family and genus. It may be seen as an elaboration of Percent Model Affinity (Novak and Bode, 1992), which is based on class and order. A large database of macroinvertebrate data was required to develop ISD methods. The database included several sites known or presumed to be impacted by specific impact types. The impact types were mostly known by chemical data or land use. These sites were grouped into the following general categories: agricultural nonpoint, toxic-stressed, sewage (domestic municipal), sewage/toxic, siltation, impoundment, and natural. Each group initially contained 20 sites. Cluster analysis was then performed within each group, using percent similarity at the family or genus level. Within each group, four clusters were identified. Each cluster was usually composed of 4-5 sites with high biological similarity. From each cluster, a hypothetical model was then formed to represent a model cluster community type; sites within the cluster had at least 50 percent similarity to this model. These community type models formed the basis for ISD (see tables following). The method was tested by calculating percent similarity to all the models and determining which model was the most similar to the test site. Some models were initially adjusted to achieve maximum representation of the impact type. New models are developed when similar communities are recognized from several streams.

Use of the ISD methods: Impact Source Determination is based on similarity to existing models of community types (see tables following). The model that exhibits the highest similarity to the test data denotes the likely impact source type, or may indicate "natural," lacking an impact. In the graphic representation of ISD, only the highest similarity of each source type is identified. If no model exhibits a similarity to the test data of greater than 50 percent, the determination is inconclusive. The determination of impact source type is used in conjunction with assessment of severity of water quality impact to provide an overall assessment of water quality.

Limitations: These methods were developed for data derived from subsamples of 100-organisms each that are taken from traveling kick samples of New York State streams. Application of these methods for data derived from other sampling methods, habitats, or geographical areas would likely require modification of the models.

ISD MODELS TABLE
NATURAL MACROINVERTEBRATE COMMUNITY TYPE

	A	B	C	D	E	F	G	H	I	J	K	L	M
PLATYHELMINTHES	-	-	-	-	-	-	-	-	-	-	-	-	-
OLIGOCHAETA	-	-	5	-	5	-	5	5	-	-	-	5	5
HIRUDINEA	-	-	-	-	-	-	-	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	-	-	-	-	-	-	-	-
SPHAERIIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-
ASELLIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-
GAMMARIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-
Isonychia	5	5	-	5	20	-	-	-	-	-	-	-	-
BAETIDAE	20	10	10	10	10	5	10	10	10	10	5	15	40
HEPTAGENIIDAE	5	10	5	20	10	5	5	5	5	10	10	5	5
LEPTOPHLEBIIDAE	5	5	-	-	-	-	-	-	5	-	-	25	5
EPHEMERELLIDAE	5	5	5	10	-	10	10	30	-	5	-	10	5
Caenis/Tricorythodes	-	-	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA	-	-	-	5	5	-	5	5	15	5	5	5	5
Psephenus	5	-	-	-	-	-	-	-	-	-	-	-	-
Optioservus	5	-	20	5	5	-	5	5	5	5	-	-	-
Promoresia	5	-	-	-	-	-	25	-	-	-	-	-	-
Stenelmis	10	5	10	10	5	-	-	-	10	-	-	-	5
PHILOPOTAMIDAE	5	20	5	5	5	5	5	-	5	5	5	5	5
HYDROPSYCHIDAE	10	5	15	15	10	10	5	5	10	15	5	5	10
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	5	5	-	-	-	20	-	5	5	5	5	5	-
SIMULIIDAE	-	-	-	5	5	-	-	-	-	5	-	-	-
Simulium vittatum	-	-	-	-	-	-	-	-	-	-	-	-	-
EMPIDIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-
TIPULIDAE	-	-	-	-	-	-	-	-	5	-	-	-	-
CHIRONOMIDAE													
Tanypodinae	-	5	-	-	-	-	-	-	5	-	-	-	-
Diamesinae	-	-	-	-	-	-	5	-	-	-	-	-	-
Cardiocladius	-	5	-	-	-	-	-	-	-	-	-	-	-
Cricotopus/ Orthocladius	5	5	-	-	10	-	-	5	-	-	5	5	5
Eukiefferiella/ Tvetenia	5	5	10	-	-	5	5	5	-	5	-	5	5
Parametriocnemus	-	-	-	-	-	-	-	5	-	-	-	-	-
Chironomus	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum aviceps -	-	-	-	-	20	-	-	10	20	20	5	-	
Polypedilum (all others)	5	5	5	5	5	-	5	5	-	-	-	-	-
Tanytarsini	-	5	10	5	5	20	10	10	10	10	40	5	5
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100

ISD MODELS TABLE (cont.)
NONPOINT NUTRIENT ENRICHMENT IMPACTED MACROINVERTEBRATE COMMUNITY TYPE

	A	B	C	D	E	F	G	H	I	J
PLATYHELMINTHES	-	-	-	-	-	-	-	-	-	-
OLIGOCHAETA	-	-	-	5	-	-	-	-	-	15
HIRUDINEA	-	-	-	-	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	-	-	-	-	-
SPHAERIIDAE	-	-	-	5	-	-	-	-	-	-
ASELLIDAE	-	-	-	-	-	-	-	-	-	-
GAMMARIDAE	-	-	-	5	-	-	-	-	-	-
Isonychia	-	-	-	-	-	-	-	5	-	-
BAETIDAE	5	15	20	5	20	10	10	5	10	5
HEPTAGENIIDAE	-	-	-	-	5	5	5	5	-	5
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-	-	5	-	-
Caenis/Tricorythodes	-	-	-	-	5	-	-	5	-	5
PLECOPTERA	-	-	-	-	-	-	-	-	-	-
Psephenus	5	-	-	5	-	5	5	-	-	-
Optioservus	10	-	-	5	-	-	15	5	-	5
Promoresia	-	-	-	-	-	-	-	-	-	-
Stenelmis	15	15	-	10	15	5	25	5	10	5
PHILOPOTAMIDAE	15	5	10	5	-	25	5	-	-	-
HYDROPSYCHIDAE	15	15	15	25	10	35	20	45	20	10
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE	5	-	15	5	5	-	-	-	40	-
Simulium vittatum	-	-	-	-	-	-	-	-	5	-
EMPIDIDAE	-	-	-	-	-	-	-	-	-	-
TIPULIDAE	-	-	-	-	-	-	-	-	-	5
CHIRONOMIDAE										
Tanypodinae	-	-	-	-	-	-	5	-	-	5
Cardiocladius	-	-	-	-	-	-	-	-	-	-
Cricotopus/ Orthocladius	10	15	10	5	-	-	-	-	5	5
Eukiefferiella/ Tvetenia	-	15	10	5	-	-	-	-	5	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-
Microtendipes	-	-	-	-	-	-	-	-	-	20
Polypedilum aviceps -	-	-	-	-	-	-	-	-	-	
Polypedilum (all others)	10	10	10	10	20	10	5	10	5	5
Tanytarsini	10	10	10	5	20	5	5	10	-	10
TOTAL	100	100	100	100	100	100	100	100	100	100

ISD MODELS TABLE (cont.)
MACROINVERTEBRATE COMMUNITY TYPES

	MUNICIPAL/INDUSTRIAL WASTES IMPACTED								TOXICS IMPACTED					
	A	B	C	D	E	F	G	H	A	B	C	D	E	F
PLATYHELMINTHES	-	40	-	-	-	5	-	-	-	-	-	-	5	-
OLIGOCHAETA	20	20	70	10	-	20	-	-	-	10	20	5	5	15
HIRUDINEA	-	5	-	-	-	-	-	-	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	5	-	-	-	5	-	-	-	5
SPHAERIIDAE	-	5	-	-	-	-	-	-	-	-	-	-	-	-
ASELLIDAE	10	5	10	10	15	5	-	-	10	10	-	20	10	5
GAMMARIDAE	40	-	-	-	15	-	5	5	5	-	-	-	5	5
Isonychia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BAETIDAE	5	-	-	-	5	-	10	10	15	10	20	-	-	5
HEPTAGENIIDAE	5	-	-	-	-	-	-	-	-	-	-	-	-	-
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caenis/Tricorythodes	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psephenus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Optioservus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Promoresia	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenelmis	5	-	-	10	5	-	5	5	10	15	-	40	35	5
PHILOPOTAMIDAE	-	-	-	-	-	-	-	40	10	-	-	-	-	-
HYDROPSYCHIDAE	10	-	-	50	20	-	40	20	20	10	15	10	35	10
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Simulium vittatum	-	-	-	-	-	-	20	10	-	20	-	-	-	5
EMPIDIDAE	-	5	-	-	-	-	-	-	-	-	-	-	-	-
CHIRONOMIDAE														
Tanypodinae	-	10	-	-	5	15	-	-	5	10	-	-	-	25
Cardiocladius	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus/ Orthocladius	5	10	20	-	5	10	5	5	15	10	25	10	5	10
Eukiefferiella/ Tvetenia	-	-	-	-	-	-	-	-	-	-	20	10	-	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-	-	5	-	-
Chironomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum aviceps	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum (all others)	-	-	-	10	20	40	10	5	10	-	-	-	-	5
Tanytarsini	-	-	-	10	10	-	5	-	-	-	-	-	-	5
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100

ISD MODELS TABLE (cont.)
SEWAGE EFFLUENT, ANIMAL WASTES IMPACTED MACROINVERTEBRATE COMMUNITY TYPE

	A	B	C	D	E	F	G	H	I	J
PLATYHELMINTHES	-	-	-	-	-	-	-	-	-	-
OLIGOCHAETA	5	35	15	10	10	35	40	10	20	15
HIRUDINEA	-	-	-	-	-	-	-	-	-	-
GASTROPODA	-	-	-	-	-	-	-	-	-	-
SPHAERIIDAE	-	-	-	10	-	-	-	-	-	-
ASELLIDAE	5	10	-	10	10	10	10	50	-	5
GAMMARIDAE	-	-	-	-	-	10	-	10	-	-
Isonychia	-	-	-	-	-	-	-	-	-	-
BAETIDAE	-	10	10	5	-	-	-	-	5	-
HEPTAGENIIDAE	10	10	10	-	-	-	-	-	-	-
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-	-	-	5	-
Caenis/Tricorythodes	-	-	-	-	-	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-
Psephenus	-	-	-	-	-	-	-	-	-	-
Optioservus	-	-	-	-	-	-	-	-	5	-
Promoresia	-	-	-	-	-	-	-	-	-	-
Stenelmis	15	-	10	10	-	-	-	-	-	-
PHILOPOTAMIDAE	-	-	-	-	-	-	-	-	-	-
HYDROPSYCHIDAE	45	-	10	10	10	-	-	10	5	-
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	-	-	-	-	-	-	-	-	-	-
SIMULIIDAE	-	-	-	-	-	-	-	-	-	-
Simulium vittatum	-	-	-	25	10	35	-	-	5	5
EMPIDIDAE	-	-	-	-	-	-	-	-	-	-
CHIRONOMIDAE										
Tanypodinae	-	5	-	-	-	-	-	-	5	5
Cardiocladius	-	-	-	-	-	-	-	-	-	-
Cricotopus/ Orthocladius	-	10	15	-	-	10	10	-	5	5
Eukiefferiella/ Tvetenia	-	-	10	-	-	-	-	-	-	-
Parametriocnemus	-	-	-	-	-	-	-	-	-	-
Chironomus	-	-	-	-	-	-	10	-	-	60
Polypedilum aviceps -	-	-	-	-	-	-	-	-	-	-
Polypedilum (all others)	10	10	10	10	60	-	30	10	5	5
Tanytarsini	10	10	10	10	-	-	-	10	40	-
TOTAL	100	100	100	100	100	100	100	100	100	100

ISD MODELS TABLE (cont.)
MACROINVERTEBRATE COMMUNITY TYPES

	SILTATION IMPACTED					IMPOUNDMENT IMPACTED									
	A	B	C	D	E	A	B	C	D	E	F	G	H	I	J
PLATYHELMINTHES	-	-	-	-	-	-	10	-	10	-	5	-	50	10	-
OLIGOCHAETA	5	-	20	10	5	5	-	40	5	10	5	10	5	5	-
HIRUDINEA	-	-	-	-	-	-	-	-	-	5	-	-	-	-	-
GASTROPODA	-	-	-	-	-	-	-	10	-	5	5	-	-	-	-
SPHAERIIDAE	-	-	-	5	-	-	-	-	-	-	-	-	5	25	-
ASELLIDAE	-	-	-	-	-	-	5	5	-	10	5	5	5	-	-
GAMMARIDAE	-	-	-	10	-	-	-	10	-	10	50	-	5	10	-
Isonychia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
BAETIDAE	-	10	20	5	-	-	5	-	5	-	-	5	-	-	5
HEPTAGENIIDAE	5	10	-	20	5	5	5	-	5	5	5	5	-	5	5
LEPTOPHLEBIIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
EPHEMERELLIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Caenis/Tricorythodes	5	20	10	5	15	-	-	-	-	-	-	-	-	-	-
PLECOPTERA	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Psephenus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
Optioservus	5	10	-	-	-	-	-	-	-	-	-	-	-	5	-
Promoresia	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenelmis	5	10	10	5	20	5	5	10	10	-	5	35	-	5	10
PHILOPOTAMIDAE	-	-	-	-	-	5	-	-	5	-	-	-	-	-	30
HYDROPSYCHIDAE	25	10	-	20	30	50	15	10	10	10	10	20	5	15	20
HELICOPSYCHIDAE/ BRACHYCENTRIDAE/ RHYACOPHILIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	5	-
SIMULIIDAE	5	10	-	-	5	5	-	5	-	35	10	5	-	-	15
EMPIDIDAE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CHIRONOMIDAE															
Tanypodinae	-	-	-	-	-	-	5	-	-	-	-	-	-	-	-
Cardiocladius	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cricotopus/ Orthocladius	25	-	10	5	5	5	25	5	-	10	-	5	10	-	-
Eukiefferiella/ Tvetenia	-	-	10	-	5	5	15	-	-	-	-	-	-	-	-
Parametriocnemus	-	-	-	-	-	5	-	-	-	-	-	-	-	-	-
Chironomus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum aviceps -	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Polypedilum (all others)	10	10	10	5	5	5	-	-	20	-	-	5	5	5	5
Tanytarsini	10	10	10	10	5	5	10	5	30	-	-	5	10	10	5
TOTAL	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

APPENDIX XI. Methods for Calculation of the Nutrient Biotic Index

Definition: The Nutrient Biotic Index (Smith, 2005) is a diagnostic measure of stream nutrient enrichment identified by macroinvertebrate taxa. The frequency of occurrences of taxa at varying nutrient concentrations allowed the identification of taxon-specific nutrient optima using a method of weighted averaging. The establishment of nutrient optima is possible based on the observation that most species exhibit unimodal response curves in relation to environmental variables (Jongman et al. 1987). The assignment of tolerance values to taxa based on their nutrient optimum provided the ability to reduce macroinvertebrate community data to a linear scale of eutrophication from oligotrophic to eutrophic. Two tolerance values were assigned to each taxon, one for total phosphorus, and one for nitrate (listed in Smith, 2005). This provides the ability to calculate two different nutrient biotic indices, one for total phosphorus (NBI-P), and one for nitrate (NBI-N). Study of the indices indicate better performance by the NBI-P, with strong correlations to stream nutrient status assessment based on diatom information.

Calculation of the NBI-P and NBI-N Calculation of the indices [2] follows the approach of Hilsenhoff (1987).

$$\text{NBI Score}_{(\text{TP or NO3}^-)} = \sum (a \times b) / c$$

Where ***a*** is equal to the number of individuals for each taxon, ***b*** is the taxon's tolerance value, and ***c*** is the total number of individuals in the sample for which tolerance values have been assigned.

Classification of NBI Scores: NBI scores have been placed on a scale of eutrophication with provisional boundaries between stream trophic status.

Index	Oligotrophic	Mesotrophic	Eutrophic
NBI-P	< 5.0	> 5.0 - 6.0	> 6.0
NBI-N	< 4.5	> 4.5 - 6.0	> 6.0

References:

Hilsenhoff, W. L., 1987, An improved biotic index of organic stream pollution. The Great Lakes Entomologist 20(1): 31-39.

Jongman, R. H. G., C. J. F. ter Braak and O. F. R. van Tongeren, 1987, Data analysis in community and landscape ecology. Pudoc Wageningen, Netherlands, 299 pages.

Smith, A.J., 2005, Development of a Nutrient Biotic Index for use with benthic macroinvertebrates. Masters Thesis, SUNY Albany, 70 pages.

APPENDIX XII. METHODS FOR ASSESSMENT OF WATER QUALITY USING FISH

A. Sampling: Sampling in wadeable streams consists of electrofishing for approximately 20 minutes, attempting to sample one pool and one riffle. A backpack electroshocker is used. All fish are identified, enumerated and released at the site.

B. Analysis of Data: Methods for interpretation of fish data with regard to water quality have not yet been standardized for northeastern streams. Four indices are presently used to assess water quality.

1. Weighted Species Richness:. Species richness is weighted by stream width using the following provisional formula where x= richness: for stream width 1-4 meters, value= x+2; for 5-9 meters, x; for 10-20 meters, x-2; for >20 meters, x-4. Maximum value= 10.

2. Percent Non-tolerant Individuals: The percentage of total individual organisms that are species considered intolerant or intermediate to environmental perturbations; this is the inverse of percent tolerant individuals. Tolerance ratings are derived from *Classification of freshwater fish species of the Northeastern United States* (Halliwell et al., 1998), with the exception of blacknose dace, which are here considered intermediate rather than tolerant.

3. Percent Non-tolerant Species: The percentage of total species that are considered intolerant or intermediate to environmental perturbations.

4. Percent Model Affinity, by Trophic Class. The highest percentage similarity of a sampled fish community with any of five models of non-impacted fish communities, by trophic class, as listed in Halliwell et al. (1998). The models are:

	A	B	C	D	E
Top carnivores	80	50	40	10	10
Insectivores	10	30	20	20	50
Blacknose dace	-	10	20	50	10
Generalist feeders	10	10	20	20	20
Herbivores	-	-	-	-	10

Overall assessment of water quality is assigned by *profile value*. Profile value = (Weighted Species Richness + 0.1[Percent Non-tolerant Individuals] + 0.1[Percent Non-tolerant Species] + 0.1[Percent Model Affinity]) ÷ 4. An adjustment factor may be applied when the number of wild or juvenile trout is high (more than 25 individuals, or more than 10% of total individuals), and the overall assessment is other than non-impacted. In such cases, the profile value is adjusted up by the percentage contribution of the trout.

Halliwell, D.B., R.W. Langdon, R.A. Daniels, J.P. Kurtenbach, and R.A. Jacobson, 1998, Classification of freshwater fish species of the Northeastern United States for use in the development of indices of biological integrity, with regional applications. Chapter 12 In: Simon, T.P., ed. Assessing the sustainability and biological integrity of water resources using fish communities. CRC Press, Inc., 671 pages.